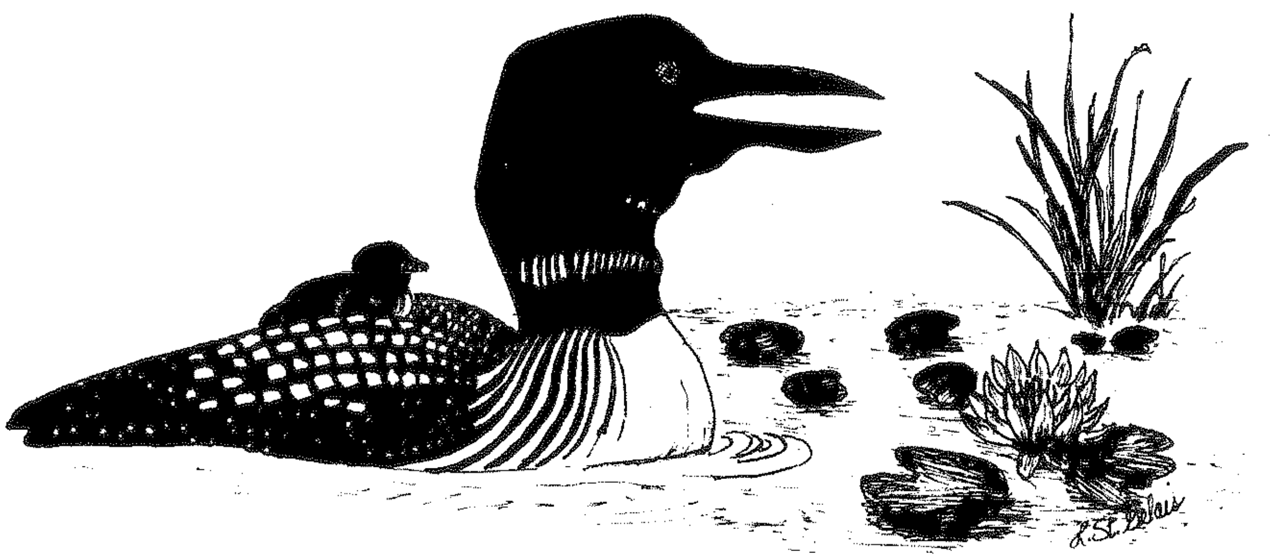
LAKE WENTWORTH

Water Quality Monitoring: 1997
Summary and Recommendations
NH LAKES LAY MONITORING PROGRAM



By: Robert Craycraft & Jeffrey Schloss

FRESHWATER BIOLOGY GROUP
University of New Hampshire

UNIVERSITY OF NEW HAMPSHIRE COOPERATIVE EXTENSION

To obtain additional information on the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at 603-862-3848 or Assistant Coordinator (Bob Craycraft) at 603-862-3546.

PARAMETERS SAMPLED

NH LAKES LAY MONITORING PROGRAM

LAY MONITORS

- **BASIC PROGRAM**
  - Secchi Disk Depth
  - Temperature Profile
  - Chlorophyll a
  - Dissolved Color
  - Total Alkalinity
  - Total Phosphorus
- **ADVANCED OPTIONS**
  - pH
  - Metalimnetic Chlorophyll a
  - Specific Conductivity
  - Hypolimnetic Total Phosphorus
  - Dissolved Oxygen
  - Bacteria
  - Fish Condition
  - Rainfall & pH
  - Aquatic Vegetation Surveys
  - Motorboat Effects
  - Watershed NPS Surveys
  - Road Salt Runoff
- **STREAM MONITORING**
  - Observational Surveys
  - Temperature
  - Specific Conductivity
  - Total Alkalinity
  - Total Phosphorus
  - Stream Flow
  - Macro-Invertebrates
  - Storm Event Sampling
  - Bacteria

Freshwater Biology Group (FBG) corroboration with the lay monitor data includes assessment of 1) physical parameters (water transparency, temperature profiles, light transmission profiles and water color); 2) chemical parameters (dissolved oxygen profiles, "free" carbon dioxide, total alkalinity, pH, total phosphorus and specific conductivity profiles); 3) biological parameters (chlorophyll a, phytoplankton community and zooplankton community). Note: in addition to the above parameters, other measurements are often collected at the discretion of the FBG or at the request of the lake association.

PREFACE

This report contains the findings of a water quality survey of Crescent Lake and Lake Wentworth, Wolfeboro New Hampshire, conducted in the summer of 1997 by the University of New Hampshire **Freshwater Biology Group (FBG)** in conjunction with the Lake Wentworth Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1997 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

1997 was the fourteenth year the Lake Wentworth Association conducted volunteer lake monitoring in conjunction with the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while John Nichols again coordinated the volunteer monitoring activities on Crescent Lake and Lake Wentworth and acted as liaison to the **Freshwater Biology Group (FBG)**. The **Freshwater Biology Group** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Lake Wentworth water quality monitoring effort in 1998 and expand upon the current database. The Lake Wentworth Association provided funding for the water quality monitoring program.

Table 1: Crescent Lake and Lake Wentworth Volunteer Monitors (1997)

Monitor Name
Don Baldwin
Brad Cook
Marge Cook
Jim Hulm
John Nichols
Laura Nichols
Alan Thompson
Elizabeth Thompson
Bud Tiedmann
We also acknowledge Al Flynn who provided on-lake transportation during our July 21 and September 3 visits to Lake Wentworth.

We also acknowledge Al Flynn who provided on-lake transportation during our July 21 and September 3 visits to Lake Wentworth.

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included, Robert Craycraft (laboratory and field team coordinator), Melinda Cowan, Shawna Durley, Michael Racine and Alex Wong while Allyssa Bentley provided additional support in the fall. We also acknowledge Nancy Lambert for her assistance in generating digital maps for participating **NH LLMP** lakes.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Dublin Garden Club, Eaton Conservation Commission, Governor's Island Club Inc., Laconia Conservation Commission, Meredith Bay Rotary Club, The New Hampshire Audubon Society, North River Lake Water Quality Audit Committee, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Berry Bay, Bow Lake Camp Owners, Chalk Pond, Lake Chocorua, Conner Pond, Cunningham Pond, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake,

Pemaquid Watershed, Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Sunset Lake, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

CRESCENT LAKE
1997 NON-TECHNICAL SUMMARY

Water quality data were collected by the Crescent Lake volunteer monitors between June 13 and August 30, 1997 while additional data were collected by the University of New Hampshire **Freshwater Biology Group (FBG)** on September 3, 1997 to augment the volunteer monitor data. Generally speaking, the 1997 Crescent Lake water quality remained excellent as summarized in Table 2. The seasonal average water transparency measured 17.5 feet (5.3 meters) characteristic of an unproductive "pristine" New Hampshire lake while the seasonal average microscopic plant "algal" abundance (1.7 parts per billion; ppb) and a single phosphorus measurement (8.8 ppb) remained low and well within the range typical of "pristine" waters. The following section further reviews the 1997 water quality data and *(Refer to Appendix A for a complete summary of the 1997 Volunteer Monitor Data)* includes a discussion of historical water quality data when applicable.

Table 2: 1997 Crescent Lake Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Crescent Lake Average (range)
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	5.3 meters (range: 4.6 – 5.7)
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	1.7 ppb (range: 1.0 – 2.8)
Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	* 8.8 ppb (single reading)
Dissolved Oxygen (ppm)	high	moderate	low	high

* *Total Phosphorus data collected by the **FBG** in the surface waters (epilimnion).*

1) Water Clarity (measured as Secchi Disk transparency) – The 1997 water transparency remained well within the range considered typical of an unproductive "pristine" New Hampshire Lake and ranged from 4.6 to 5.7 meters during the summer months (Figures 9 and 10).

The 1997 seasonal average Secchi Disk transparency measured at Site 6 Center was deeper (clearer water) than the 1996 seasonal average value and remained well within the range of historical Secchi Disk transparency measurements documented between 1984 and 1996 (Figure 17).

2) Microscopic plant abundance "greenness" (measured as chlorophyll *a*) – The 1997 chlorophyll *a* concentrations were low and remained within the range characteristic of an unproductive New Hampshire lake throughout the summer months (Figure 9).

The 1997 seasonal average chlorophyll *a* concentration was one of the lower (less "greenness") levels documented between 1984 and 1996 and reflects the clearer seasonal water transparency documented in Crescent Lake (Figure 18).

3) Background (dissolved) water color: often perceived as a "tea" color in our more highly stained lakes – The 1997 Crescent Lake dissolved color concentration averaged 15.1 chloroplatinate units (cpu) and fell within the classification of a slightly "tea" colored lake (Table 3). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

Table 3. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range (cpu)	Classification
0 - 10	clear
10 - 20	slightly colored
20 - 40	light tea color
40 - 80	tea colored
> 80	highly tea colored

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes. - Total phosphorus concentrations measured in the surface waters (**epilimnion**), 8.8 parts per billion (ppb), and near the lakebottom, 12.7 ppb, were low when measured by the **Freshwater Biology Group**. However, the sample collected near the lakebottom was slightly higher than the concentration of 10 ppb considered sufficient to cause an algal bloom (e.g. greener water).

5) Resistance against acid precipitation (measured as total alkalinity) – The 1997 Crescent Lake seasonal alkalinity measured 5.3 milligrams per liter (mg/l) which is considered typical of a lake with a moderate vulnerability to acid precipitation according to the standards devised by the New Hampshire Department of Environmental Services (Table 4). Generally speaking, the geology of the region does not contain the appropriate mineral content (e.g. limestone) to increases the buffering capacity of our surface waters. Thus, lakes in the vicinity (e.g. Lake Winnipesaukee, Merrymeeting Lake, Mirror Lake) have naturally low alkalinities.

Table 4. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range (mg/l)	Classification
< 0	Acidified
0 - 2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

6) Temperature and dissolved oxygen profiles – Temperature profiles collected by the Crescent Lake volunteer monitors indicate the lake becomes stratified into two distinct thermal layers when the weather is calm (a warm upper water layer, **epilimnion**, overlying a layer of rapidly decreasing temperatures, **thermocline**). The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can favor oxygen depletion near the lake-bottom. Dissolved oxygen data collected by the **Freshwater Biology Group** remained high and above the concentration of 3 parts per million (considered the minimum concentration for the successful growth and reproduction of most warmwater fish species) down to about 5.0 meters (just above the lakebottom). *Refer to Figure 25 for a visual depiction of the dissolved oxygen data.*

7) Based on the current and historical water quality data, Crescent Lake would be considered a relatively clear and unproductive "pristine" New Hampshire lake that borders a higher level of lake productivity, **mesotrophy**. While the current water quality is high, it is important for you to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) entering the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake as the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained** having it pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and result in early failure, costing thousands of dollars to repair or replace. It is important to make sure the watershed residents are well-educated on water quality related issues. Numerous publications are available through University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services as well as several other local, state and federal agencies. It is imperative that future activities within the Lake Crescent Lake watershed are carefully thought out before implementation if water quality degradation is to be minimized. *Refer to the "Comments and Recommendations" section for more detailed suggestions and to the section "Understanding Lake Aging" for a list of publications pertinent to watershed protection.*

8) Comparisons between the **Freshwater Biology Group** and the Crescent Lake lay monitor data indicate the volunteer monitors are doing an excellent job of collecting water quality data.

LAKE WENTWORTH
1997 NON-TECHNICAL SUMMARY

Water quality data were collected by the Lake Wentworth volunteer monitors between June 23 and September 19, 1997 while additional water quality data were collected by the University of New Hampshire **Freshwater Biology Group** on July 21 and on September 3, 1997 to augment the volunteer monitor data. Generally speaking, the 1997 Lake Wentworth water quality remained excellent as summarized in Table 5. The seasonal average water transparency measured 23.1 feet (7.0 meters) characteristic of an unproductive "pristine" New Hampshire lake while the seasonal average microscopic plant "algal" abundance (1.8 parts per billion; ppb) and phosphorus concentration (6.8 ppb) remained low and well within the range typical of "pristine" waters. While the overall water quality was excellent, variations were evident among the Lake Wentworth sampling locations (Refer to Figure 8 for sampling locations). The following section reviews the 1997 water quality data and discusses variations among the sampling locations *(Refer to Appendix A for a complete summary of the 1997 Volunteer Monitor Data)* while historical water quality data are also discussed when applicable.

Table 5: 1997 Lake Wentworth Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Lake Wentworth Average (range)
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	7.0 meters (range: 5.0 – 7.8)
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	1.8 ppb (range: 0.9 – 2.4)
Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	* 6.8 ppb (range: 6.1 – 8.8)
Dissolved Oxygen (ppm)	high	moderate	low	# Low-Moderate

* *Total Phosphorus data collected by the **FBG** in the surface waters **(epilimnion)**.*
\# *Dissolved oxygen data collected by the **FBG** in the bottom waters **(hypolimnion)**.*

1) **Water Clarity (measured as Secchi Disk transparency)** – The 1997 seasonal Secchi Disk transparency measurements documented at the Lake Wentworth deep sampling stations (Sites 1 Fullers, 2 Triggs and 12 Governors Deep) were high throughout the summer months and remained well within the range considered typical of an unproductive New Hampshire lake (Figures 11 through 16). The seasonal average water transparency was similar among the three deep sampling stations (6.9 meters at Sites 2 Triggs and 12 Governors Deep and 7.1 meters at Site 1 Fullers).

The 1997 seasonal Lake Wentworth water transparency measurements were deeper (clearer water) at each of the deep sampling stations (1 Fullers, 2 Triggs and 12 Governors Deep) relative to the average values documented in 1996 (Figures 19, 21 and 23).

2) Microscopic plant abundance "greenness" (measured as chlorophyll *a*) – The 1997 seasonal chlorophyll *a* measurements documented at the Lake Wentworth deep sampling stations remained low throughout the summer months and well within the criteria of an unproductive New Hampshire Lake (Figures 19, 21 and 23). Variations among the three sampling stations were evident with the highest (greenest water) seasonal chlorophyll *a* concentration documented at Site 1 Fullers, 2.0 parts per billion, while the chlorophyll *a* concentration measured 1.6 parts per billion at Sites 2 Triggs and 12 Governors Deep.

The 1997 seasonal chlorophyll *a* concentrations documented at Sites 2 Triggs and 12 Governors Deep were lower (less "greeness") than the 1996 seasonal average values while the 1997 seasonal average chlorophyll *a* concentration documented at Site 1 Fullers was higher (greener water) than the 1996 average (Figures 20, 22 and 24).

3) Background (dissolved) water color: often perceived as a "tea" color in our more highly stained lakes – The 1997 Lake Wentworth dissolved color concentration averaged 15.4 chloroplatinate units (cpu) and fell within the classification of a slightly "tea" colored lake (Table 6). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

Table 6. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range (cpu)	Classification
0 - 10	clear
10 - 20	slightly colored
20 - 40	light tea color
40 - 80	tea colored
> 80	highly tea colored

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes. - Total phosphorus concentrations measured in the surface waters (**epilimnion**) were low when collected by the **Freshwater Biology Group**, range: 6.1 – 8.8 parts per billion (ppb), which is well within the range considered typical of an unproductive New Hampshire Lake. Supplemental bottom water (**hypolimnetic**) total phosphorus concentrations (range: 6.7 – 11.7 ppb) were generally slightly higher than the corresponding surface concentrations but did not reach problematic levels.

5) Dissolved salt concentrations (measured as Specific Conductivity) – Specific Conductivity data collected by the **Freshwater Biology Group** (July 21, 1997) remained low throughout the water column (range: 37.0 – 43.0 micro-Siemans) at Sites 1 Fullers and 12 Governors Deep. High Specific Conductivity values can be an indication of heavy fertilizer applications, faulty septic systems and other improper land use practices that can negatively impact water quality.

6) Resistance against acid precipitation (measured as total alkalinity) and lake acidity (measured as pH) – The 1997 Lake Wentworth alkalinity measured 4.9 milligrams per liter (mg/l) which is considered typical of a lake with a moderate vulnerability to acid precipitation according to the standards devised by the New Hampshire Department of Environmental Services (Table 7). Generally speaking, the geology of the region does not contain the appropriate mineral content (e.g. limestone) to increases the buffering capacity of our surface waters. Thus, lakes in the vicinity (e.g. Lake Winnipesaukee, Merrymeeting Lake, Mirror Lake) have naturally low alkalinities.

Table 7. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range (mg/l)	Classification
< 0	Acidified
0 - 2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

Surface water pH measurements, collected by the **Freshwater Biology Group** on July 21, remained high (6.9-7.2 units) and well within the tolerable range for most aquatic organisms.

7) Temperature and dissolved oxygen profiles – Temperature profiles collected by the Lake Wentworth volunteer monitors indicate the lake becomes stratified into three distinct thermal layers during the summer months (a warm upper water layer, **epilimnion**, overlying a layer of deep and cold bottom waters, **hypolimnion**. The two layers separated by a zone of rapidly decreasing temperatures, **thermocline**). The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can favor oxygen depletion near the lake-bottom. Dissolved oxygen data collected by the **Freshwater Biology Group** indicate the dissolved oxygen remained high and above the concentration of 5 parts per million (considered the minimum concentration for the successful growth and reproduction of most coldwater fish species) down to the lakebottom of Site 1 Fullers and down to about 18 meters at Site 12 Governors Deep on July 21, 1997 (Figures 26 and 27). Dissolved oxygen measurements collected latter in the year (September 3, 1997) indicate the dissolved oxygen concentrations became depleted more quickly and remained above 5 ppm only down to about 10.0 meters at Sites 1 Fullers and 12 Governor's Deep (Figures 26 and 27). Relative to Sites 1 Fullers and 12 Governors Deep, dissolved oxygen concentrations measured at Site 2 Triggs remained above 5 ppm deeper into the water column (down to about 13.5 meters) as depicted in Figure 25.

8) Based on the current and historical water quality data, Lake Wentworth would be considered an unproductive "pristine" New Hampshire lake. While the current water quality is high, it is important for you to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) entering the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake as the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained** having it pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and result in early failure, costing thousands of dollars to repair or replace. It is important to make sure the watershed residents are well-educated on water quality related issues. Numerous publications are available through University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services as well as several other local, state and federal agencies. It is imperative that future activities within the Lake Wentworth watershed are carefully thought out before implementation if water quality degradation is to be minimized. *Refer to the "Comments and Recommendations" section for more detailed suggestions and to the section "Understanding Lake Aging" for a list of publications pertinent to watershed protection.*

9) Comparisons between the **Freshwater Biology Group** and the Lake Wentworth lay monitor data indicate the volunteer monitors are doing an excellent job of collecting water quality data.

COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating association, including the Lake Wentworth Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in the lake and through continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) Frequent "weekly" water quality samples, necessary to assess the current condition of Lake Wentworth, should continue to be collected whenever possible. We recommend initiating lake sampling early in the season (April/May) to document the lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color and Secchi Disk transparency measurements. Phosphorus samples are also recommended from both the in-lake and the tributary sampling sites. When tributary samples are collected, streamflow measurements/estimates should be included whenever possible.

3) Changing land use within the Lake Wentworth watershed, the surrounding land that drains into the lake, can accelerate the natural aging process (what is known as eutrophication). A typical lake fills in and becomes more productive (i.e. greener) on a geological time frame (thousands of years). However, this process can be accelerated and occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide applications, installing proper erosion control structures, etc.) that are set up to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the **NH LLMP** and the U S Natural Resource Conservation Service **(US NRCS)**, which provides the layperson with a systematic method for recognizing and evaluating erosion, sedimentation and related non-point source (NPS) pollutant problems in New Hampshire watersheds. Contact *Jeff Schloss (862-3848)* for further information.

TABLE OF CONTENTS

REPORT FIGURES

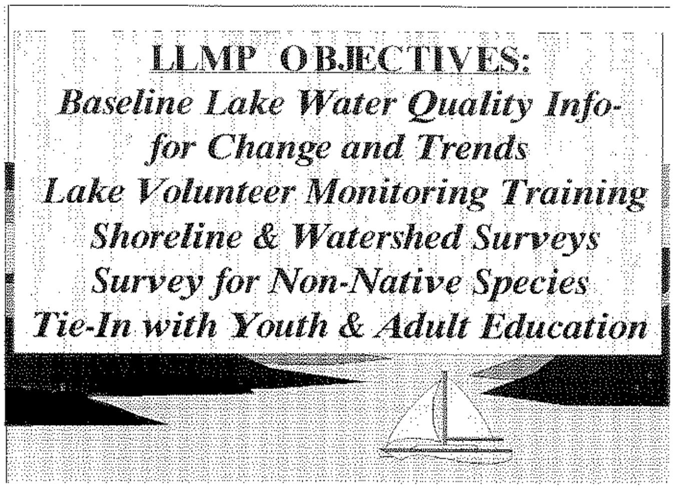
TABLES

INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

1997 marked the twentieth year of operation for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

Figure 1. LLMP Objectives



The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets and investigations of water quality and indicator organisms (food web analysis, fish condition, stream invertebrates, the presence of algal toxins and their fate, the sources of mercury and the accumulation in aquatic food chains). The key ingredients responsible for the success of the program include innovative cost-share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

Figure 2. Awards & Recognition

AWARDS and RECOGNITION

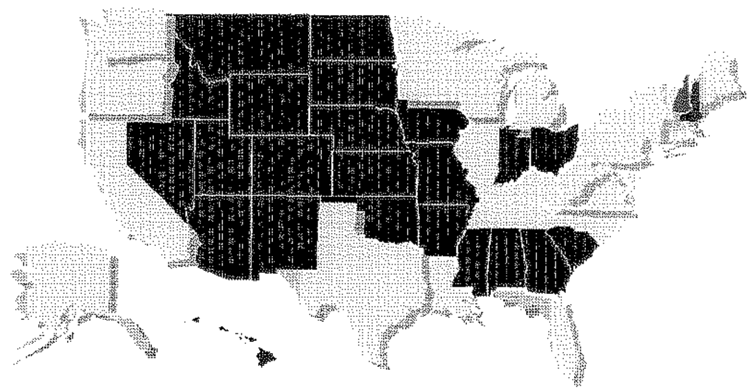
1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal
1991- Renew America Success Award
Environmental Success Index
UN Environmental Programme
Soviet Embassy Reception
White House Environment Breifing
1992- EPA Administrators Award
Environmental Exchange Network
1993- NH Lakes Association
1994- Fourth National Citizens' Volunteer Monitoring Conference
EPA Office of Watersheds Award
1995- Co-editors Volunteer Monitor Newsletter (Spring Issue)
Winnipesaukee Watershed Project
1996 - Fifth National Citizens' Volunteer Monitoring Conference

The 1997 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program**. National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Figure 2).

Our experience with data analysis for volunteer monitoring programs was awarded with SeaGrant funding to produce a data management and interpretation manual for coastal monitoring groups in conjunction with the Riverwatch Network. Our "Follow the Flow" nonpoint source evaluation technique and our "Watershed Natural Resource Inventory" material were chosen as two of four watershed assessment methods that will be taught-supported with training videos and manuals funded by the region-wide United States Geological Survey water resources program.

Figure 3. National LLMP Support to Volunteer Monitoring Programs

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 24 States.



Light gray shading denotes LLMP assisted states

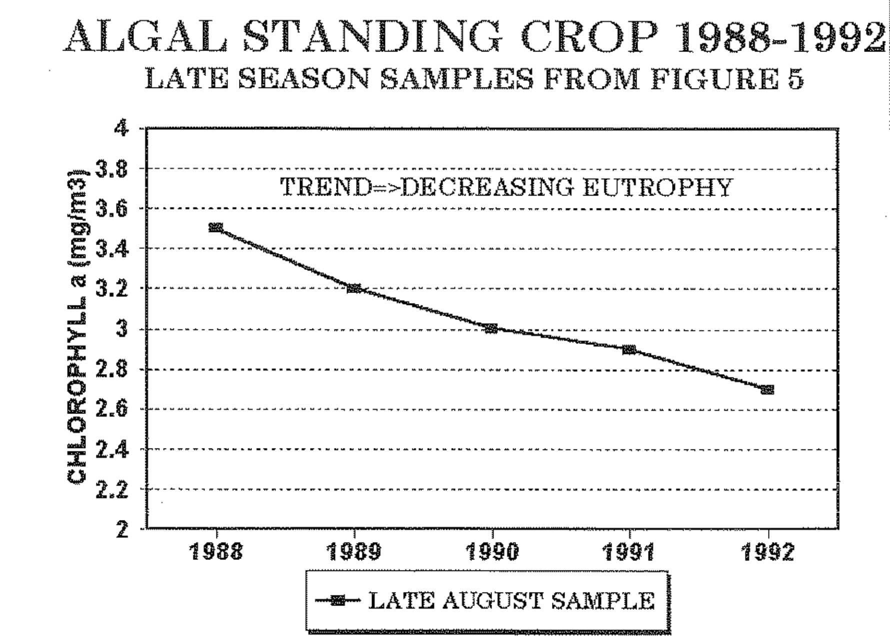
We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty four states and eleven countries (Figure 3)!

Importance of Long-term Monitoring

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

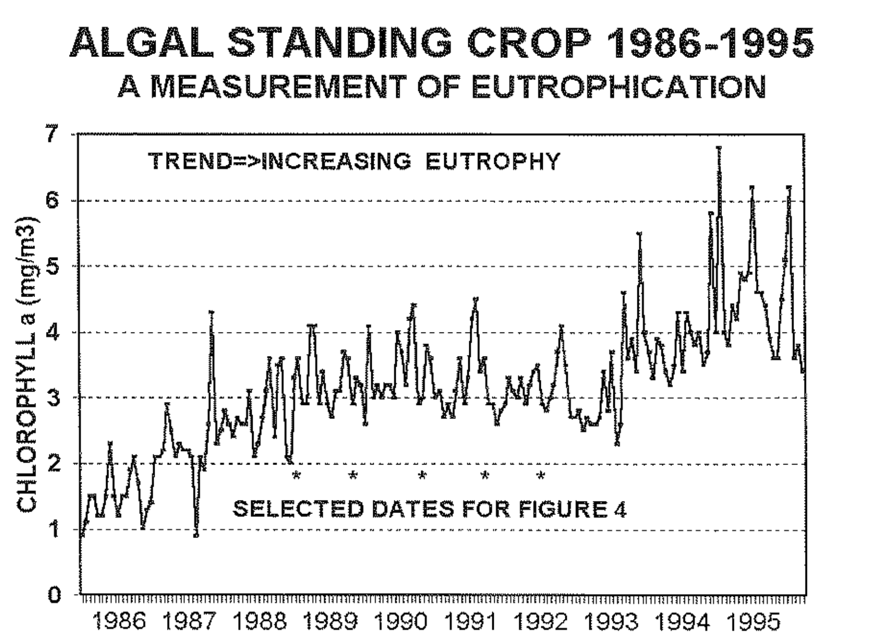
For almost two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Figure 4.



Consider the hypothetical data depicted in Figure 4. Sampling only once a year during August from 1988 to 1992 produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection.

Figure 5



The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Study

1997 was the fourteenth that water quality monitoring was undertaken by the **Freshwater Biology Group** in conjunction with Lake Wentworth Association. The monitoring program was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on one open water deep sampling station in Crescent Lake (Site 6 Center) and on three open water deep sampling stations (Sites 1 Fullers, 2 Triggs and 12 Governors Deep) in Lake Wentworth (Figures 7 and 8). Supplemental tributary sampling was also undertaken as part of a Lake Wentworth phosphorus budget conducted in conjunction with the New Hampshire Department of Environmental Services.

The primary purpose of this report is to discuss results of the 1997 monitoring season with emphasis on current conditions of Lake Wentworth and Crescent Lake including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1996 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

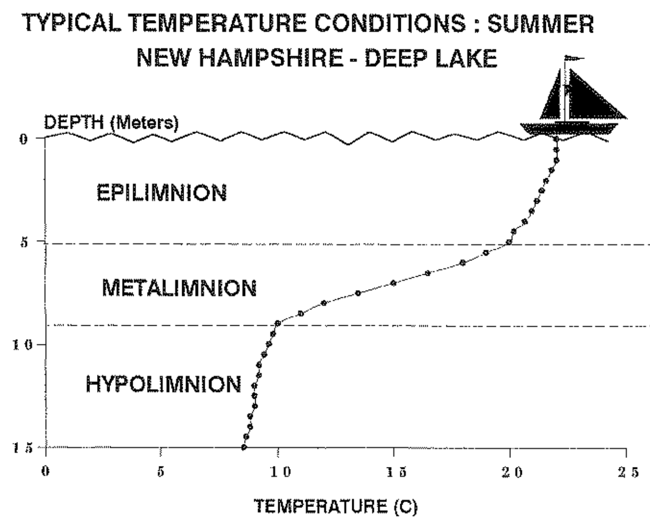
Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (figure 10). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and nonliving particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes. The 1996 average transparency for participating **NH LLMP** lakes was 5.4 meters with a range of 1.5 to 14.6 meters.

Figure 6



Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg m^3 (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg m^3. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m^3 and 7 mg m^3. The 1996 seasonal average chlorophyll *a* concentration for participating **NH LLMP** lakes was 3.1 mg m^3 with a range of 0.4 to 22.4 mg m^3.

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lakebottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. The 1996 seasonal average dissolved color for participating **NH LLMP** lakes was 27.1 ptu with a range of 3.4 to 111.7 ptu.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

Streamflow

Streamflow is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micro**mhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS).

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddisflies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

Inspect your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

Flush the cooling system, bilge areas and live wells with tap water.

Leave unused bait behind and discard bait bucket water away from surface waters.

Keep your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

Share information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

Report any sightings to the **New Hampshire Lakes Lay Monitoring Program.** Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

Jeff Schloss
Lakes Lay Monitoring Program
55 College Road 109 Pettee Hall
University of New Hampshire
Durham NH 03824-3512
(603) 862-3848

UNIVERSITY OF NEW HAMPSHIRE COOPERATIVE EXTENSION

NEW HAMPSHIRE LAKES LAY MONITORING

Understanding Lake Aging (Eutrophication)

by: Robert Craycraft Educational Program Coordinator,
New Hampshire Lakes Lay Monitoring Program
University of New Hampshire
109 Pettee Hall, Durham, NH 03824
603-862-3546 FAX: 603-862-0107
email: bob.craycraft@unh.edu

and Jeff Schloss UNH Cooperative Extension Water Resources Specialist

A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear, pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients which enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to natural attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from pristine to enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 8 below for a summary of commonly used eutrophication parameters.

Table 8: Eutrophication Parameters and Categorization

Parameter	Oligotrophic "pristine"	Mesotrophic "transitional"	Eutrophic "enriched"
Chlorophyll a (*ug*/l) *	<3.0	3.0-7.0	>7.0
Water Transparency (meters) *	>4.0	2.5-4.0	<2.5
Total Phosphorus (*ug*/l) *	<15.0	15.0-25.0	>25.0
Dissolved Oxygen (saturation) #	high to moderate	moderate to low	low to zero
Macroscopic Plant (Weed) Abundance	low	moderate	high

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
 # Denotes dissolved oxygen concentrations near the lakebottom.

Oligotrophic lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lakebottom. **Eutrophic** lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lakebottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lakebottom.

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic and an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period which should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of forested lands are being developed, culminating in an increased susceptibility of these lakes to sediment and nutrient loadings which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". A "healthy" lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well managed pasture: nutrients grow grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- <u>Removal of shoreside vegetation and loss of wetlands</u> - shoreside vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- Excessive fertilizer applications - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested.

- Increased organic matter loading - organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- Septic problems - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- Loss of vegatative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of a greater load of suspended and dissolved pollutants into your lake.

How can you minimize your water quality impacts?

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody in the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested (the UNH Soils Analytical Laboratory offers soil testing for a nominal fee, contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and what type you really need. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties.
- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create

or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).

- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

  Septic Systems, How they work and how to keep them working. $1.00/ea University of New Hampshire Publications Center (603) 862-2346

  Pipeline: Fall 1995 Vol. 6, No. 4. Maintaining Your Septic System-A Guide for Homeowners. ($0.20 ea. plus shipping & handling). 1-800-624-8301

- Maintain shoreside (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

  Planting Shoreland Areas (no charge) University of New Hampshire Cooperative Extension Publication Center. (603) 862-2346

  A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water. North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1,. Meredith NH 03253-9266 (603) 279-6546

  Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audobon Society of New Hampshire. 3 Silk Farm Road, Concord NH 03301 (603) 224-9909 (free for towns, $5.00 for others).

- If you have shoreland property review the New Hampshire Comprehensive Shoreland Protection Act (CSPA). The CSPA sets legal regulations aimed at protecting water quality If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator at* (603) 271-3503.

Rainfall... People... and Lake Water Quality

By: Alan L .Baker
Professor of Aquatic Ecology
University of New Hampshire

High quality lakes will always remain an invaluable attraction to people, thus an important element of New Hampshire's economy. Questions about changes in water quality and clarity are often asked. Now data which have been gathered by University of New Hampshire researchers, in cooperation with many volunteer monitors, are beginning to provide some answers to questions such as: *Have our lakes degraded in this century? Is water quality currently deteriorating? What is causing changes to occur?* Now we can begin to answer these questions.

Dynamic Lakes

In order to understand the answers, one must have some awareness of Limnology - the study of the geologic, physical, chemical and biological dynamics of lakes. It is important to be alert to the changing nature of lakes, their sensitivity to disturbances, and their likelihood to degrade or improve in quality in response to poor or good protection strategies.

It is possible to identify many characteristics that determine the uniqueness of each lake and help to distinguish a blue jewel from a septic waste depot. Volunteer monitors from the **N.H. Lakes Lay Monitoring Program (LLMP)** have amassed data from more than 100 New Hampshire lake sites over the past decade. The objective of this effort, established in 1978, was to develop information to scientifically document long-term trends in water quality.

It is now possible to understand the kinds of disturbances that modify the characteristics of a lake for better or worse. This cooperative effort between lakeshore property owners and UNH researchers has established how lake water quality changes over the decades. Based upon accumulated data it is possible to use a model to predict these events.

The Overview

Although each New Hampshire lake is unique, and there is a diversity of lake types in the state, the **LLMP** data reveal a remarkably common pattern in the "behavior" of most lakes. Researches anticipated that multiple sites within any given lake would have the same characteristics. There is also strong evidence that large and small lakes follow a similar pattern of changes, within the ice-free period of a single year as well as through nearly two decades of observations. This is quite a surprise! *How can unique lakes in unique watershed "behave" in such a similar manner?*

The "long-term" changes in water quality characteristics are not always monotonously negative, but appear to fluctuate corresponding to 11-year cycles of solar flares or sunspots. What is the role of human behavior? There is no cyclic pattern to human activity on lakes.

Why, for example, did Squam Lake become greener from 1979 through 1984, then suddenly clarify in 1985? Why did the clarity of nearly all lakes in the ***LLMP*** *program improve in 1985? Why did the chlorophyll (the major pigment in microscopic plants) decrease significantly in the same year? Furthermore, why was total phosphorous in the water very low in 1985? Why was there a relatively high Acid Neutralizing Capacity in that year? (ANC is the capacity of a lake to absorb or buffer higher levels of acidity in the water). Finally, why have all these water quality parameters changed together in the reverse direction from 1986 to 1993?*

A few lakes have "misbehaved" and followed opposite trends during the same period, but this can be attributed to their unique characteristics, and to site-specific circumstances.

The Hunch

New Hampshire is a relatively small state. Despite other diversities, our lakes are all subjected to the climate we enjoy at 43° to 44° North latitude. The whimsical nature of New England weather, difficult to predict, variable from season to season and year to year, is well known. *Could it be that our lakes are responding to climatic variation and global warming? What was unique about 1985?*

A reasonable hunch was that changes in total rainfall could be the "pied piper" playing the tune to which the lakes have danced. A comparison of rainfall data from 30 National Oceanographic and Atmospheric Administration weather stations confirmed that the state is basically a single climate region. While rainfall is much higher in some areas than others, the pattern is similar no matter where one looks. A dry year is a dry year and a wet year is a wet year, statewide. The record rainfall between July 1984 and June 1985 occurred during a period of sub-normal rainfall relative to 30-year averages.

So! We have a clue.

The Model

The majority of New Hampshire's lakes are what is known as "nutrient limited." This means that certain nutrients, especially phosphorus and nitrogen, when present in lake water stimulate high levels of growth in microscopic aquatic plants such as algae and phytoplankton. Humans, along with other creatures, process these nutrients quickly and deposit them in lakes or in water flowing down a watershed.

In addition, most watersheds in New Hampshire are small and have steep topography. The streams within these watersheds are typically short and fast-flowing, delivering rainwater to lakes very quickly. Thus, episodes of high rainfall deliver more nutrients by washing them into lakes from watersheds. Prolonged periods (up to one year) of high rainfall lead to more nutrient loading and higher total phosphorus levels, therefore greener and less transparent lakes. In addition, sulfur dioxide in rainwater-- the ingredient that causes acid rain -- and solutes (dissolved acids) collected within the watershed, lowers the ANC of our lakes, i.e., the capacity of lakes to buffer the effects of acidity is diminished.

At its present state of development, the LLMP model suggests that the total volume of rainfall is the cause of both seasonal and long-term annual changes in lake water quality throughout New Hampshire. Most lakes "improved" in dry years such as 1985 and "degrade" in wetter years such as 1984 and 1986. The model works to the extent that the loading of nutrients into nutrient-deprived lakes is dependent on rainfall, and this appears to be the case.

Further verification of the model comes from the few more productive lakes, i.e., those higher in naturally occurring levels of nutrients. The "richer" in nutrients a lake, the "greener" it tends to be. Such "rich" lakes tend to be "diluted" by the loading of stormwater running off the watershed. This again directly implicates rainwater as the "piedpiper" which causes such lakes to be somewhat less productive, therefore "improved," during wet years.

Implications

At least two important predications can be developed when interpreting the LLMP model. First, changes in rainfall volume associated with global warming will influence lake water quality directly. If New Hampshire becomes drier, the lakes will tend to remain transparent and on that basis, will likely "improve" in water quality. Otherwise, a wetter future will likely deplete water quality to some extent.

Second, the model provides substantial evidence that our lakes are sensitive to changes in nutrient loading. Such loading can be controlled to a large extent by the choices people make with regard to activities within a watershed area. Such activities include land use and development patterns and practices within the watershed area, as well as along the shoreland areas of lakes and streams. Human activity on the water can also have some impact on nutrient loading of lakes (see Spring 1995 *Lakeside*).

Efforts to minimize nutrient loading can make a difference. Such practices as:

- routine pumping of septic systems
- erosion control
- maintaining buffer and wooded areas near lakes and within watershed
- control of storm water run-off from roof tops, impermeable driveways and parking lots

all help to minimize nutrient transport to lakes.

Future Concerns

While we can predict lake water quality parameters based upon weather patterns in a given year or over a period of years, there are a number of issues that require more comprehensive and thoughtful policy development if New Hampshire's lakes are going to remain the blue gems that we take for granted.

here are some of the unresolved issues:

- The survival of each lake given the multiple uses which they receive now, and will receive in the next millennium.
- The study of lake capacity, or use beyond which a lake becomes undesirable.
- The possibility that lakes will lose their aesthetic and economic value if they visibly degrade over time.

- The establishment of a comprehensive statewide lake use plan to manage our lakes effectively.

Reprinted from the Summer 1995 issue of Lakeside
A Publication of the New Hampshire Lakes Association

The Zebra Mussel Threat to New Hampshire

By: Jeff Schloss
UNH Cooperative Extension
Water Resource Specialist

The Zebra Mussel, a non-native freshwater mollusk that has successfully invaded a host of lakes and rivers throughout northeastern and central North America, continues its expansion towards New Hampshire. In the past three years, primarily due to the efforts of state agencies like **New Hampshire Fish Game** and **New Hampshire Department of Environmental Services (DES)**, the New Hampshire Lakes Association as well as local lake associations, residents and visitors have started to become aware of this non-native aquatic nuisance. All of these groups have been assisted by the University of New Hampshire (UNH) SeaGrant and Water Resource Extension Programs of the Northern New England Mussel Watch.

These tenacious little shellfish have caused almost a billion dollars worth of trouble in the Great Lakes region of the US and Canada. More recently, they impacted water suppliers and a federal fish hatchery on Lake Champlain in neighboring Vermont to the tune of millions of dollars. Thus, there is great concern with this potential threat to New Hampshire's precious fresh waters. But given the fact that many lakes and streams have very soft waters (they contain low mineral content especially that of calcium which is important for reproduction and shell construction) how concerned should we be?

TABLE 9:

ZEBRA MUSSEL COLONIZATION POTENTIAL

Based on environmental tolerances of known wild and lab populations in Europe and North America

(modified from C. O'Neill, NY SeaGrant Zebra Mussel Clearing House 6/95)

Variable	High Potential	Moderate Potential	Low Potential	Very Low Potential	NH Summer Range *	NH Summer Average *
SALINITY (ppt)	0 - 1	1 - 4	4 - 10	10 - 35	none	less than 0
CALCIUM (mg/L)	> 25	20 -25	9 - 20	< 9	<1 - 32	3.4
pH (units)	7.4 - 8.5	7.0 - 7.4 8.5 - 9.0	6.5 -7.0	< 6.5 > 9.0	4.4 - 9.6	6.0
WATER TEMP.°C)	18 - 25	16 -18 25 -29	9 -15 28 - 30	< 8 > 30	9.8 - 30	varies by depth
DISSOLVED OXYGEN (ppm)	8 - 10	6 - 8	4 - 6	< 4	0 - 12	generally > 6 in upper layer
CONDUCTIVITY (umhos at 25°C)	> 83	37 - 82	22 - 36	< 21	13 - 350	55
CHLOROPHYLL	Greater than	2 ppb	CHL a	(algae level)	0.1 - 144	7.2

* Summer upper water (epilimnetic) layer data from UNH Freshwater Biology Group and NH DES Limnology Center
data bases 1978 to 1993; total of 597 NH lakes sampled.
> = greater than; < = less than.

Table 9 breaks down the colonization potential of Zebra Mussels according to the water conditions they encounter. As can be seen, most of our fresh waters meet their temperature, algae, salinity and oxygen requirements. Limiting colonization for a majority of our lakes is pH and calcium content. It is ironic that the conditions that hurt us most in combating acid rain impacts may be our saving grace in preventing dense colonies of mussels. Of the two parameters, calcium is the more critical in that the pH of even the softest waters can increase to more tolerable levels due to the photosynthetic activity of submerged plants and algae (the removal of carbon dioxide from the water raises the pH in dense weed beds and in more productive lakes).

Care must be taken in concluding how safe we really are from infestation. These data are only from known zebra mussel habitats. In the lab, zebra mussels have successfully reproduced at salinities as high as 15 parts per thousand. Also, the lower limit of the calcium requirement continues to fall with time.

So which of our waters are most susceptible to Zebra Mussel colonization? Table 10 lists those waters with calcium concentrations of 9 parts per million or greater. There are two lakes that have water conditions highly conducive to colonization, three lakes with moderate potential and at least 16 lakes with low potential (an additional 8 lakes have calcium levels just under 9 parts per million). Most are located somewhere near the Connecticut River that has limestone deposits that can contribute calcium to nearby waters. The others are in the lower Merrimack River valley. There are also some close to the sea coast. UNH Sea Grant has initiated monitoring for adult mussels on the majority of these lakes through existing **NH LLMP (UNH)**, **VLAP (DES)** and Cooperative Extension/SeaGrant monitoring programs.

Table 10: Lakes Most Susceptible to Zebra Mussel Colonization.

Lake		Town
Horseshoe	(low risk)	Merrimack
Harris Pond		Pelham
Kimball Pond		Canterbury
Post Pond		Lyme
Sebbins Pond	(med. risk)	Bedford
Wilder Lake		Lebanon
Cobbetts Pond		Windham
Crystal Lake		Manchester
Ogontz Lake		Lyman
Moses Pond		Plainfield
Dorrs Pond		Manchester
World End Pond		Salem
Otternick Pond		Hudson
Fish Pond		Columbia
Flints Pond		Hollis
Taylor River		Hampton
Kendall Pond		Londonderry
Stevens Pond		Manchester
Lime Pond	(high risk)	Columbia
Mill Pond		Portsmouth

While our current understanding of the mussels may allow for a brief sigh of relief on the part of our low calcium lakes, boaters and anglers should still continue to take the proper precautions on <u>all</u> waters. We are still continuing to amass all of the available information and research on these persistent little shellfish. The most frightening information indicates that these critters are becoming more at home in a wider range of water conditions; the water conditions within the mussels American range are much wider than those found in the mussels native habitat in Central Europe. Zebra Mussels have only been in our country since sometime around 1988 while they have been known to occur in large freshwater lakes such as the Black, Caspian and Aral seas for hundreds if not thousands of years. This means that the invading mussels have been adapting quickly. Remember also that our native shellfish have adapted very well to our soft waters.

That is the reason zebra mussel warning signs have been posted with information posters and pamphlets at public areas and boat-launch sites. These materials are in place at lakes with higher calcium levels as well as high boat traffic areas. In addition, these precautions will minimize the risk of introducing non-native weeds like milfoil and other new plant and animal invaders that could eventually find a way into New Hampshire.

Reprinted from the August 1995 issue of Lakeside
A Publication of the New Hampshire Lakes Association

REFERENCES

American Public Health Association.(APHA) 1989. Standard Methods for the Examination of Water and Wastewater 17th edition. APHA, AWWA, WPCF.

Baker, A.L. 1973. Microstratification of phytoplankton in selected Minnesota lakes. Ph. D. thesis, University of Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Chase, V.P., L.S. Deming and F. Latawiec. 1995. Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audobon Society of New Hampshire.

Edmondson, W.T. 1937. Food conditions in some New Hampshire lakes. In: Biological survey of the Androscoggin, Saco and coastal watersheds. (Report of E.E. Hoover.) New Hampshire Fish and Game Commission. Concord, New Hampshire.

Estabrook, R.H., J.N. Connor, K.D. Warren, and M.R. Martin. 1987. New Hampshire Lakes and Ponds Inventory. Vol. III. Staff Report No. 153. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M.R. Martin and W.M. Henderson. 1988. New Hampshire Lakes and Ponds Inventory. Vol. IV. Staff Report No. 156. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M.R. Martin, P.M. McCarthy, D.J. Dubis, and W.M. Henderson. 1989. New Hampshire Lakes and Ponds Inventory. Vol. V. Staff Report No. 166. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., P.M. McCarthy, M. O'Loan, W.M. Henderson, and D.J. Dubis. 1990. New Hampshire Lakes and Ponds Inventory. Vol. VI. NHDES-WSPCD-90-3. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M. O'Loan and W.M. Henderson. 1991. New Hampshire Lakes and Ponds Inventory. Vol. VII. NHDES-WSPCD-91-3. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M. O'Loan, W.M. Henderson and K.L. Perkins. 1992. New Hampshire Lakes and Ponds Inventory. Vol. VIII. NHDES-WSPCD-92-6. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., K. Faul and W.M. Henderson. 1993. New Hampshire Lakes and Ponds Inventory. Vol. IX. NHDES-WSPCD-93-3. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., K. Faul and W.M. Henderson. 1994. New Hampshire Lakes and Ponds Inventory. Vol. X. NHDES-WSPCD-94-4. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., W.M. Henderson and S. Ashley. 1996. New Hampshire Lakes and Ponds Inventory. Vol. XII. NHDES-WSPCD-96-6. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-water receiving lakes. Arch. Hydrobiol. 89:189-207

Gallup, D.N. 1969. Zooplankton distributions and zooplankton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Haney, J.F. and D.J. Hall. 1973. Sugar-coated Daphnia: a preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Hoover, E.E. 1936. Preliminary biological survey of some New Hampshire lakes. Survey report no. 1. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hoover, E.E. 1937. Biological survey of the Androscoggin, Saco, and coastal watersheds. Survey report no. 2. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hoover, E.E. 1938. Biological Survey of the Merrimack watershed. Survey report no. 3. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hutchinson, G.E. 1967. A treatise on limnology, Vol. 2. John Wiley and Sons, New York.

Lind, O.T. 1979. Handbook of common methods in limnology. C.V. Mosby, St. Louis.

Lorenzen, M.W. 1980. Use of chlorophyll-Secchi Disk relationships. Limnol. Oceanogr. 25:371-372.

McCafferty, W.P. 1983. Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and their relatives. Jones and Bartlett Publishers. Boston MA.

Merritt, R.W. and K.W. Cummins. 1995. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company. Dubuque, Iowa

New Hampshire Water Supply and Pollution Control Commission. 1981. Classification and priority listing of New Hampshire lakes. Vol. II (Parts 1-6). Staff report no. 121. Concord, New Hampshire.

New Hampshire Water Supply and Pollution Control Commission. 1982. Classification and priority listing of New Hampshire lakes. Vol. III. Staff report no. 121. Concord, New Hampshire.

New Hampshire Water Supply and Pollution Control Commission. 1983. New Hampshire Lakes and Ponds Inventory. Vol. I. Staff report no. 133. Concord, New Hampshire.

New Hampshire Water Supply and Pollution Control Commission. 1985. New Hampshire Lakes and Ponds Inventory. Vol. II. Staff report no. 133. Concord, New Hampshire.

Newell, A.E. 1960. Biological survey of the lakes and ponds in Coos, Grafton and Carroll Counties. Survey report no. 8a. New Hampshire Fish and Game Department. Concord, New Hampshire.

Newell, A.E. 1970. Biological survey of the lakes and ponds in Cheshire, Hillsborough and Rockingham Counties. Survey report no. 8c. New Hampshire Fish and Game Department. Concord, New Hampshire.

Newell, A.E. 1977. Biological survey of the lakes and ponds in Sullivan, Merrimack, Belknap and Strafford Counties. Survey report no. 8b. New Hampshire Fish and Game Department. Concord, New Hampshire.

Schindler, D.W., et al. 1985. Long-term ecosystem stress: Effects of years of experimental acidification on a small lake. Science. 228:1395-1400.

Schloss, J.A., A.L. Baker and J.F. Haney. 1989. Over a decade of citizen volunteer monitoring in New Hampshire: The New Hampshire Lakes Lay Monitoring Program. Lake and Reservoir Management.

Sprules, W.G. 1980. Zoogeographic patterns in size structure of zooplankton communities with possible applications to lake ecosystem modeling and management. in W.C. Kerfoot ed. Evolution and Ecology of Zooplankton Communities. University Press of New England. Dartmouth. pp. 642-656.

Uttermohl, H. 1958. Improvements in the quantitative methods of phytoplankton study. Mitt. int. Ver. Limnol. 9:1-25.

U.S. Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

Vollenweider, R.A. 1969. A manual on methods for measuring primary productivity in aquatic environments. International Biological Programme. Blackwell Scientific Publications, Oxford.

Warfel, H.E. 1939. Biological survey of the Connecticut Watershed. Survey Report 4. N.H. Fish and Game. Concord, New Hampshire.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Philadelphia.

Wetzel, R.G. and G.E. Likens. 1979. Limnological Analyses. W.B. Saunders Co. Philadelphia.

REPORT FIGURES

Figure 7. Location of the 1997 Crescent Lake deep sampling station, Site 6 Center, Wolfeboro New Hampshire.

Crescent Lake

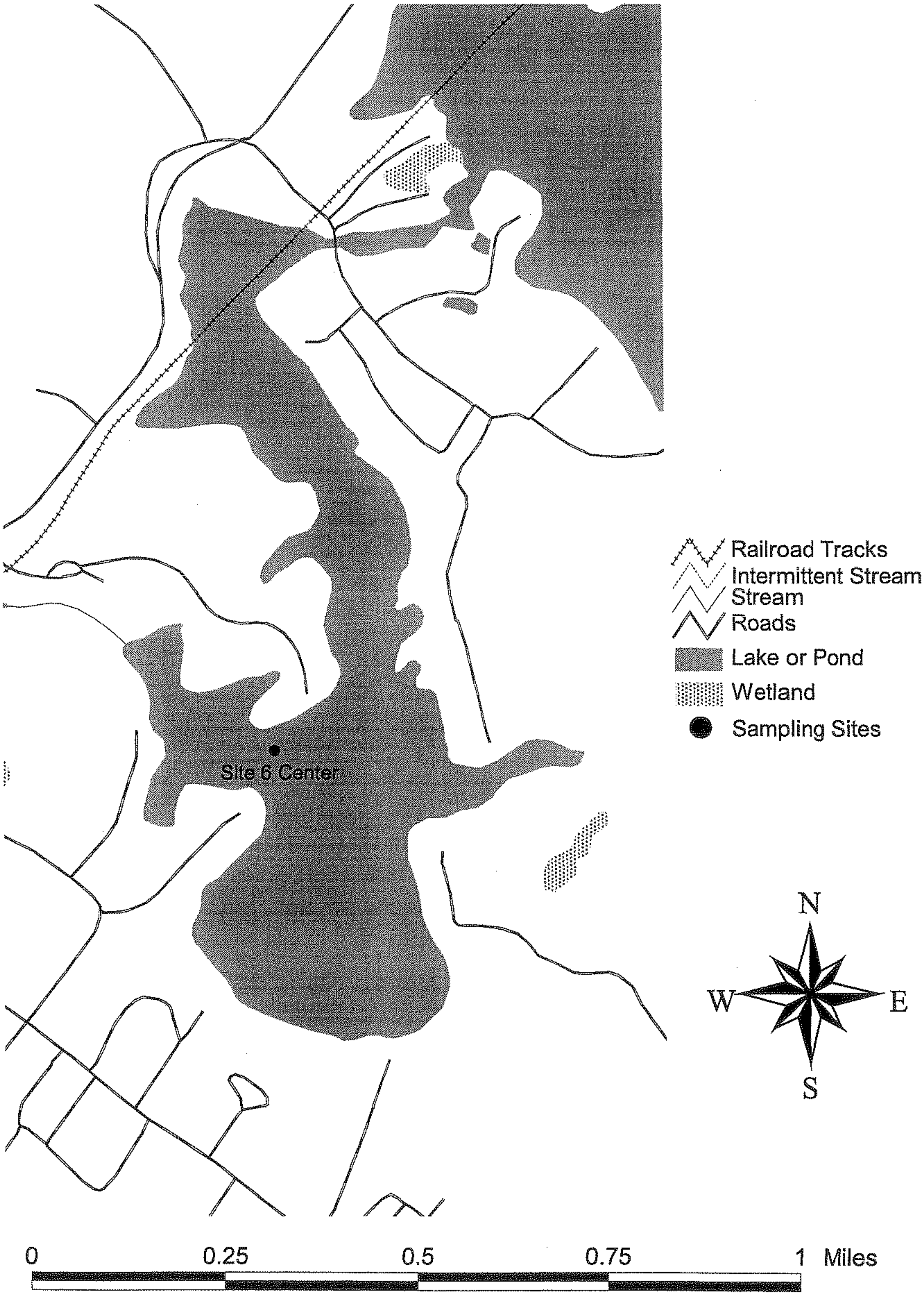


Figure 8. Location of the 1997 Lake Wentworth in-lake sampling locations (Sites 1 Fullers, 2 Triggs and 12 Governors Deep), Wolfeboro New Hampshire. The historical tributary sampling stations are also depicted on the map.

Lake Wentworth

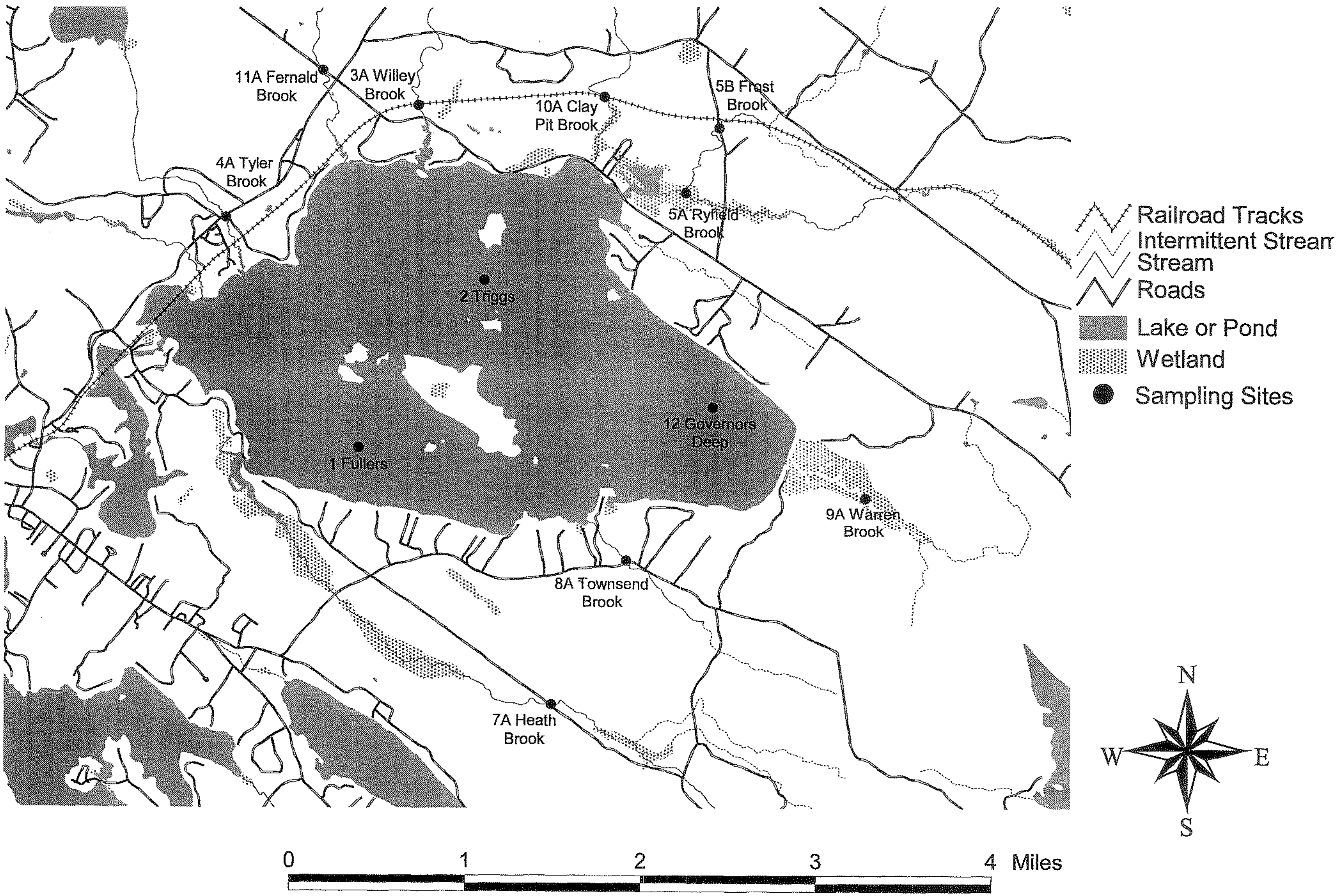
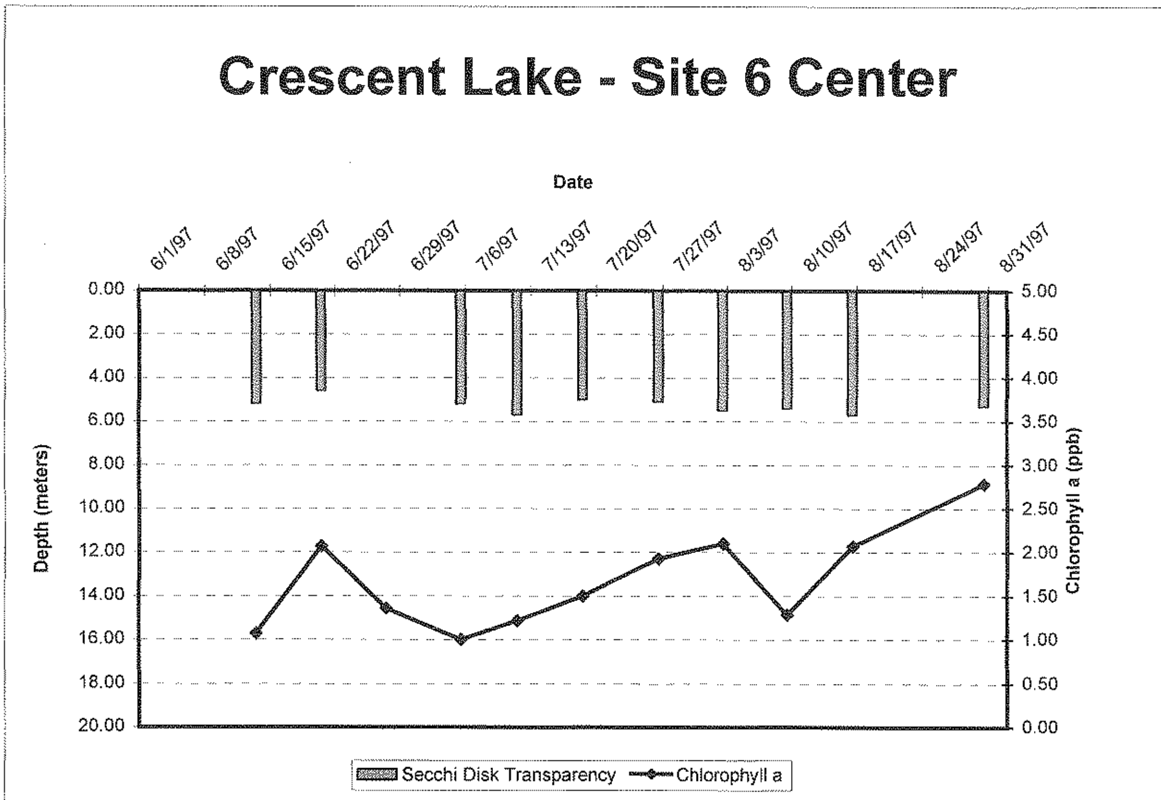


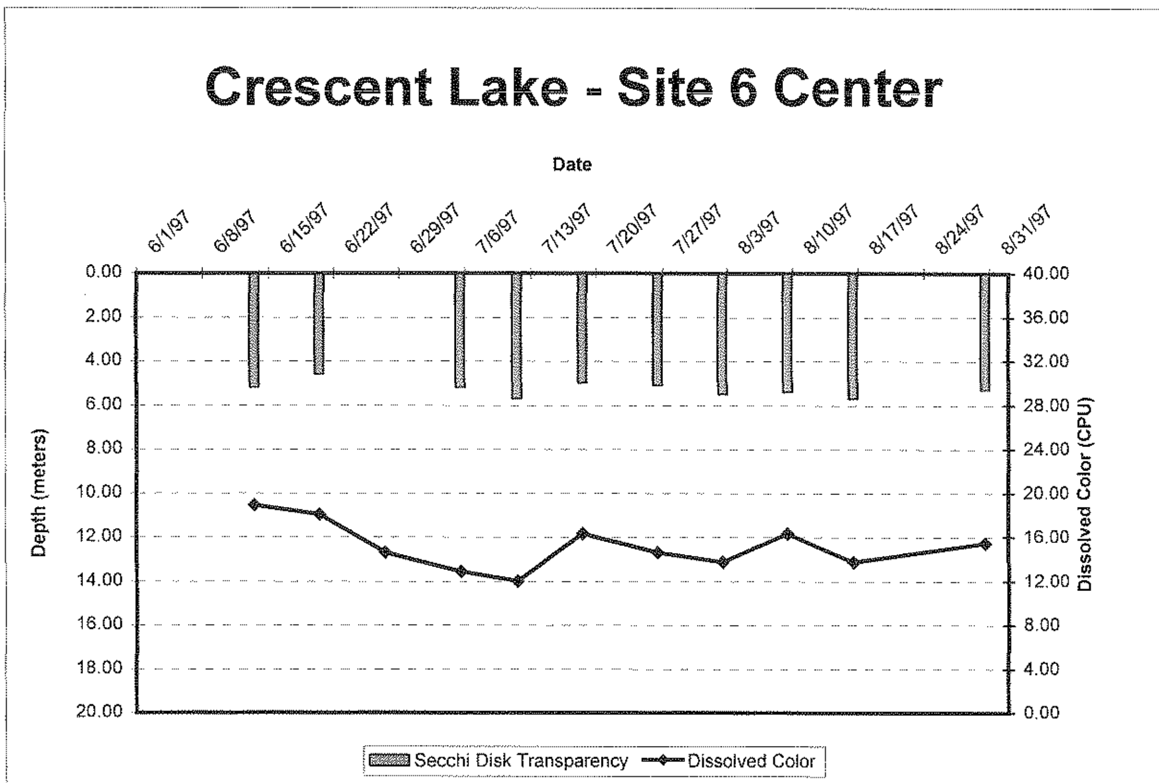
Figure 9. Crescent Lake, 1997. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 6 Center. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 10. Crescent Lake, 1997. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 6 Center. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).



Crescent Lake - Site 6 Center
Date
6/1/97
6/8/97
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Chlorophyll a (ppb)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Secchi Disk Transparency
Chlorophyll a

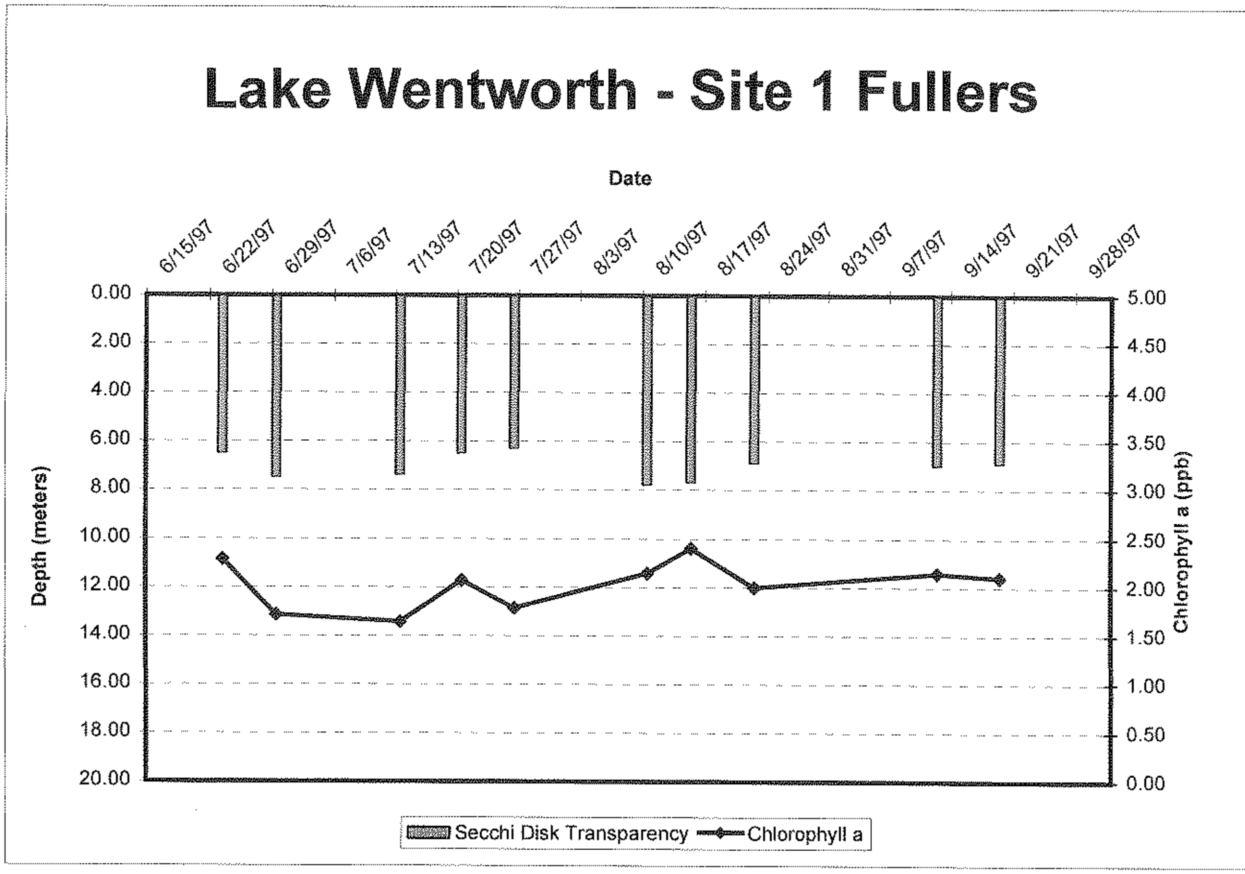


Crescent Lake - Site 6 Center
Date
6/1/97
6/8/97
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Dissolved Color (CPU)
40.00
36.00
32.00
28.00
24.00
20.00
16.00
12.00
8.00
4.00
0.00
Secchi Disk Transparency
Dissolved Color

Figure 11. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 1 Fullers. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 12. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 1 Fullers. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Lake Wentworth - Site 1 Fullers
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
9/7/97
9/14/97
9/21/97
9/28/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Chlorophyll a (ppb)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Secchi Disk Transparency
Chlorophyll a

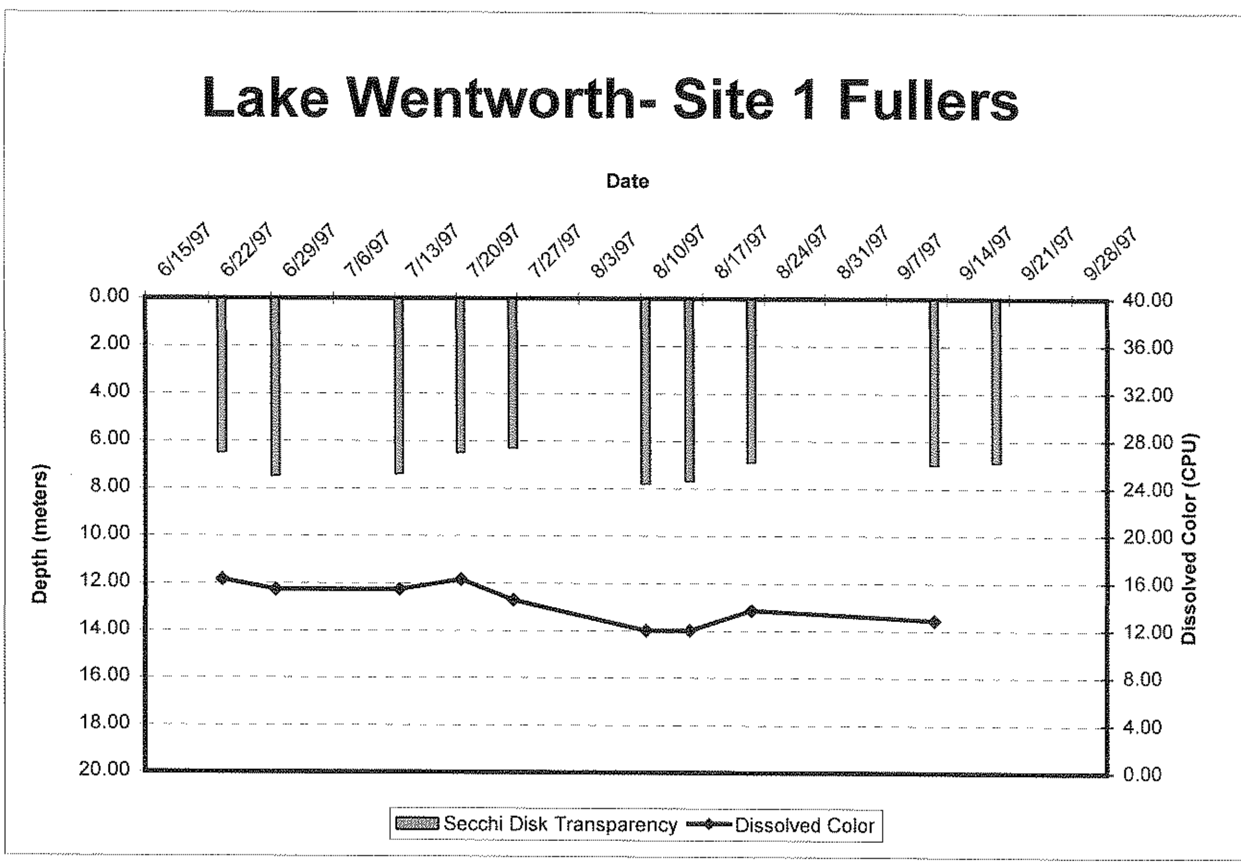
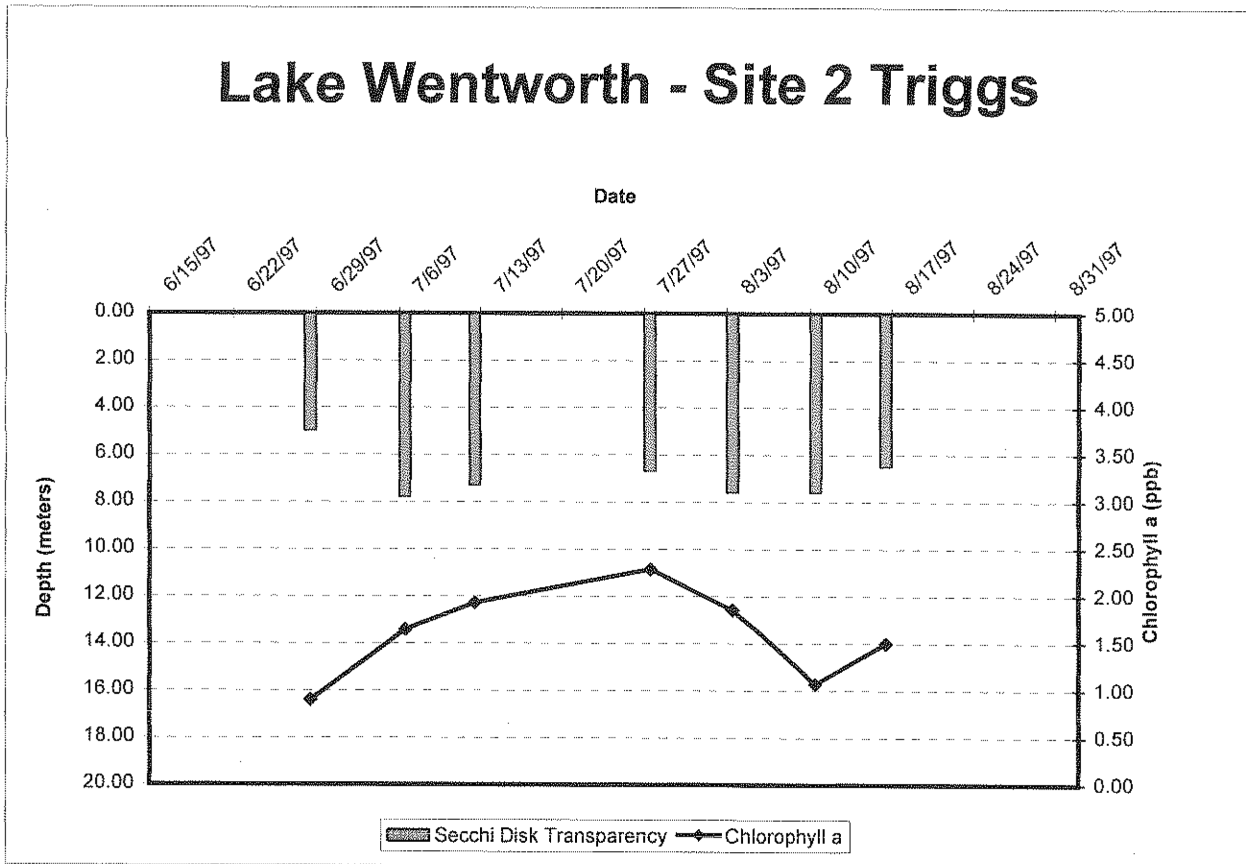

Lake Wentworth- Site 1 Fullers
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
9/7/97
9/14/97
9/21/97
9/28/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Dissolved Color (CPU)
40.00
36.00
32.00
28.00
24.00
20.00
16.00
12.00
8.00
4.00
0.00
Secchi Disk Transparency
Dissolved Color

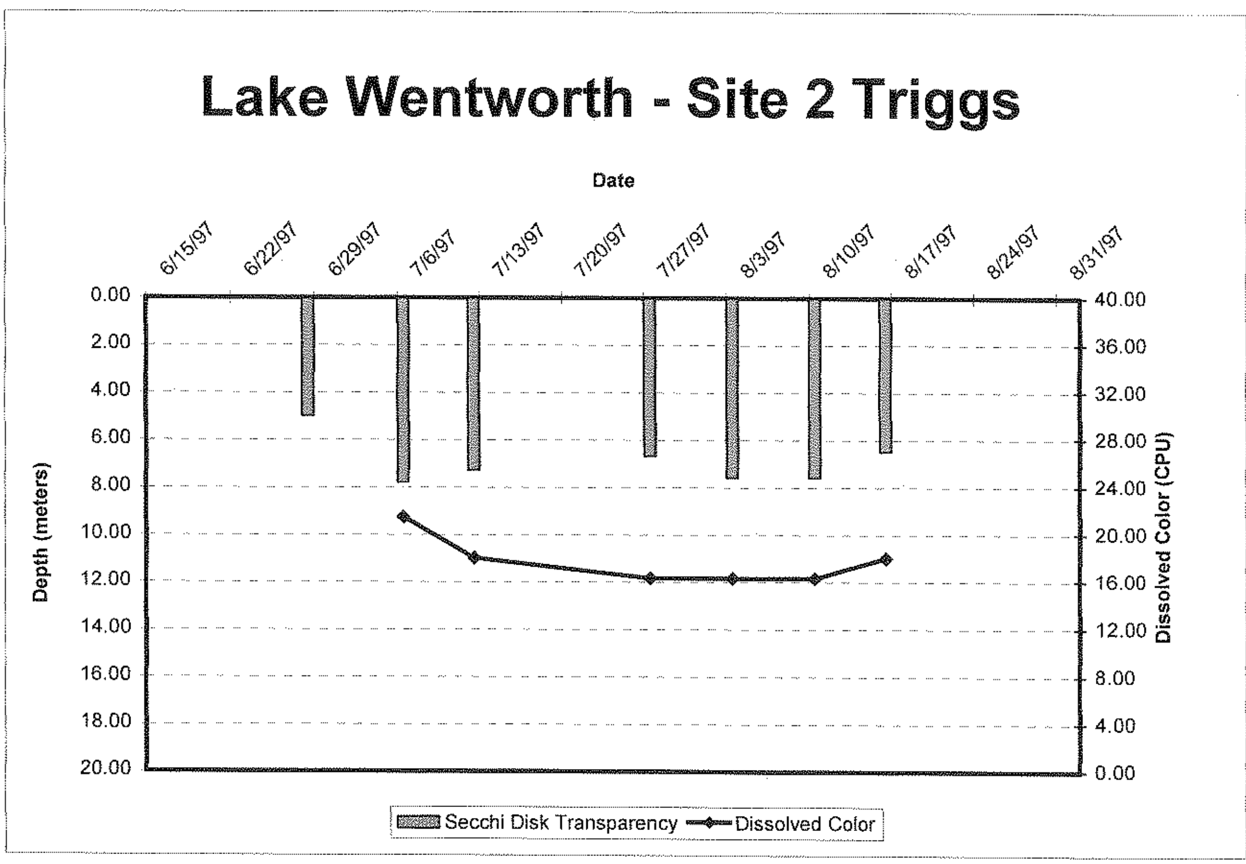
Figure 13. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 2 Triggs. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 14. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 2 Triggs. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).



Lake Wentworth - Site 2 Triggs
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Chlorophyll a (ppb)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Secchi Disk Transparency
Chlorophyll a

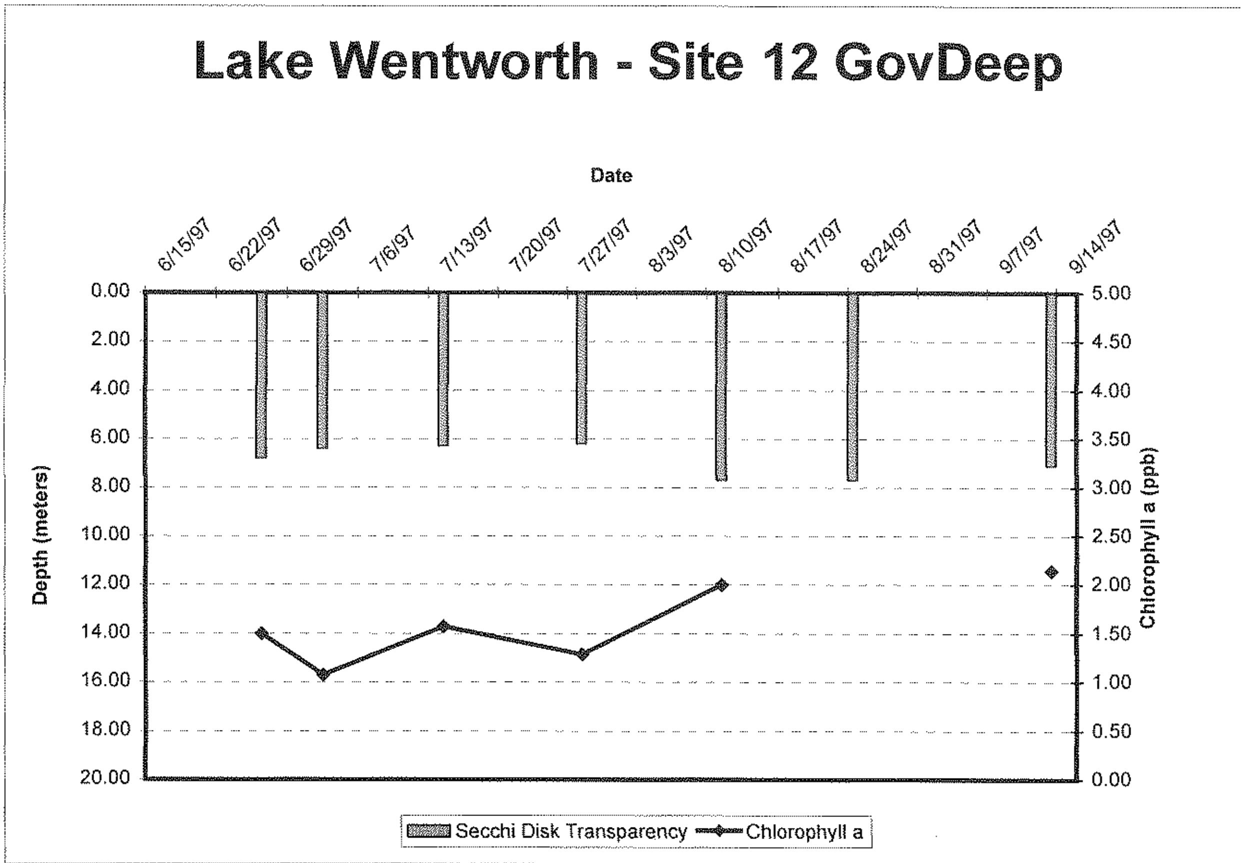


Lake Wentworth - Site 2 Triggs
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Dissolved Color (CPU)
40.00
36.00
32.00
28.00
24.00
20.00
16.00
12.00
8.00
4.00
0.00
Secchi Disk Transparency
Dissolved Color

Figure 15. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 12 Governors Deep. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 16. Lake Wentworth, 1997. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 12 Governors Deep. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Lake Wentworth - Site 12 GovDeep
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
9/7/97
9/14/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Chlorophyll a (ppb)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Secchi Disk Transparency
Chlorophyll a

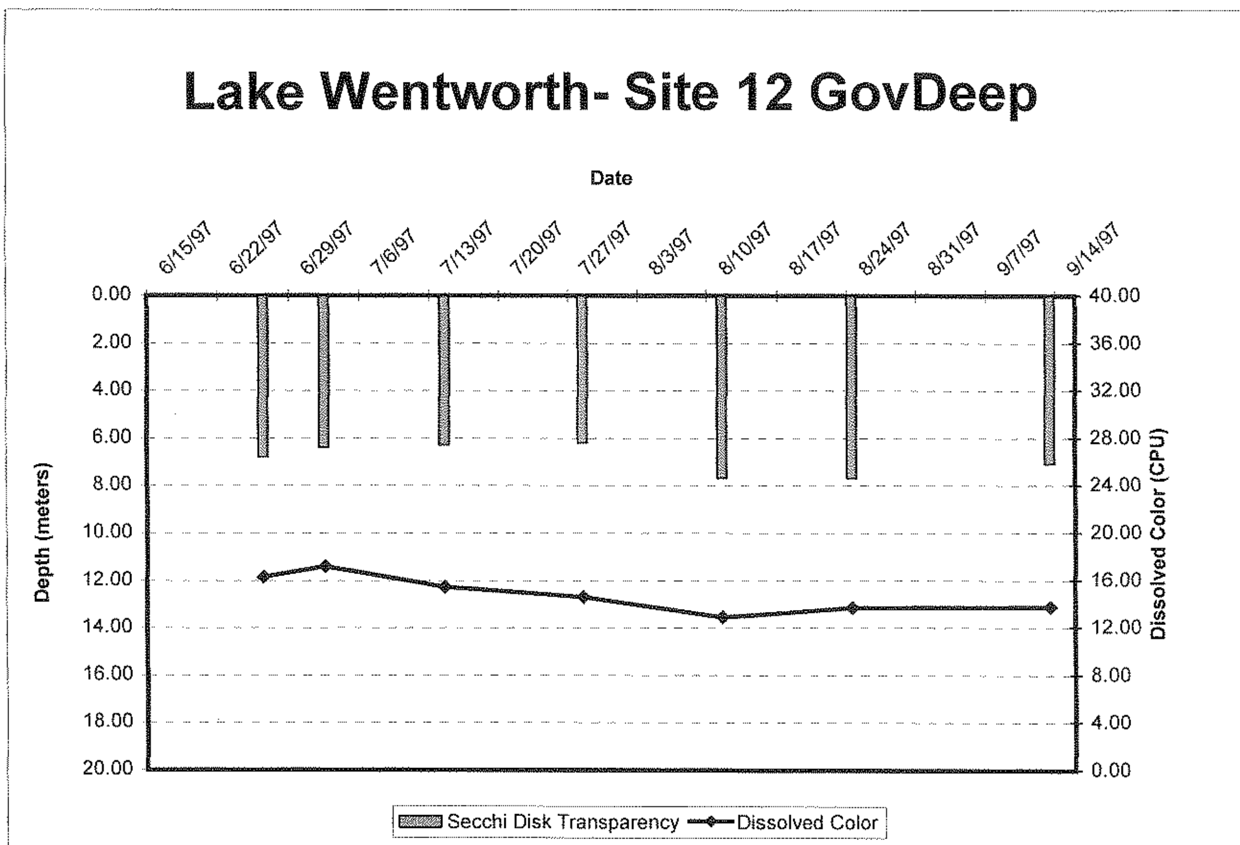
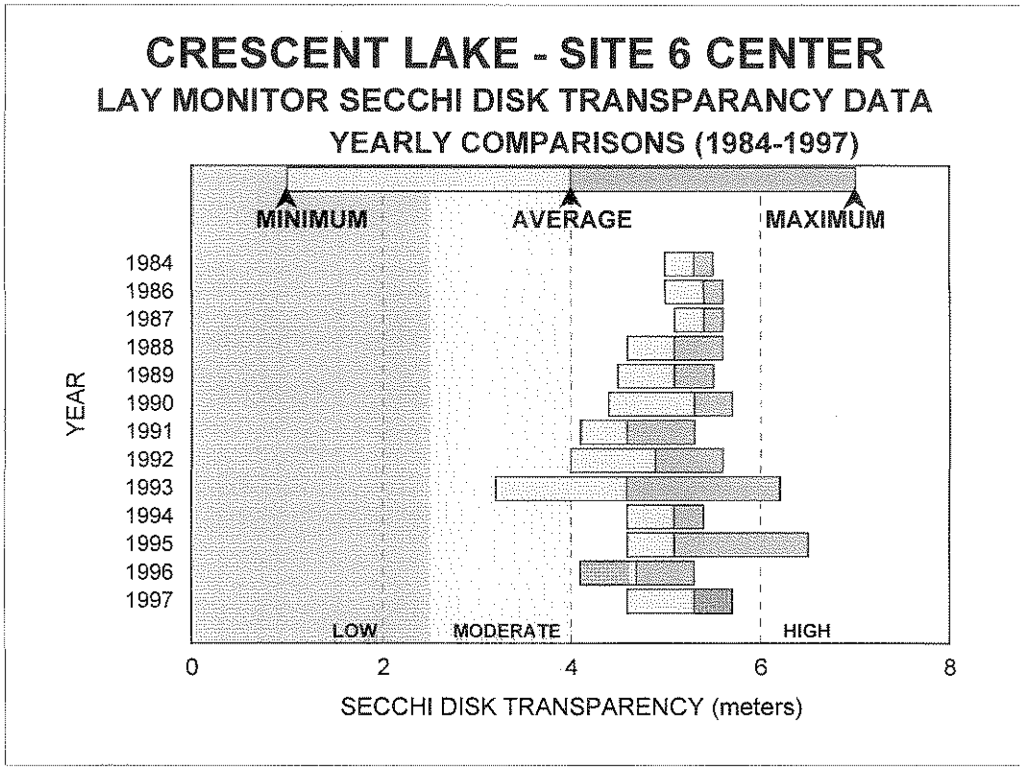
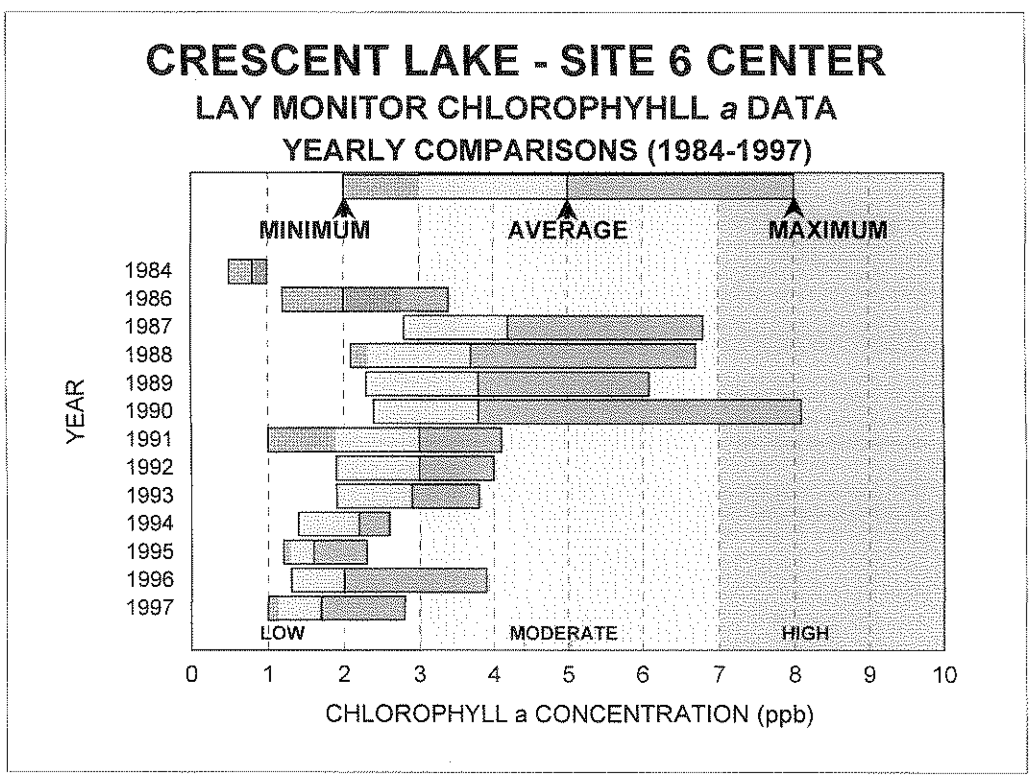

Lake Wentworth- Site 12 GovDeep
Date
6/15/97
6/22/97
6/29/97
7/6/97
7/13/97
7/20/97
7/27/97
8/3/97
8/10/97
8/17/97
8/24/97
8/31/97
9/7/97
9/14/97
Depth (meters)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Dissolved Color (CPU)
40.00
36.00
32.00
28.00
24.00
20.00
16.00
12.00
8.00
4.00
0.00
Secchi Disk Transparency
Dissolved Color

Figure 17. Comparison of the 1997 Crescent Lake, Site 6 Center, lay monitor Secchi Disk transparency data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1984-1996). The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk transparency the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 18. Comparison of the 1997 Crescent Lake, Site 6 Center, lay monitor chlorophyll *a* data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1984-1996). The shaded regions on the graph denote the ranges characteristic of low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).



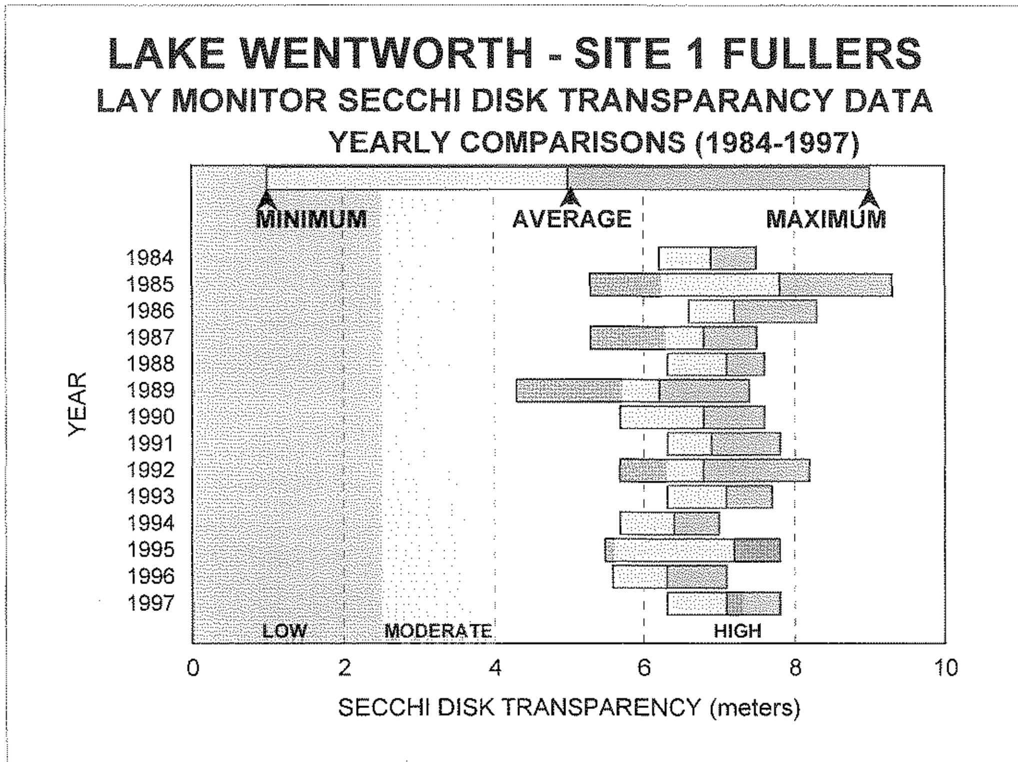
CRESCENT LAKE - SITE 6 CENTER
LAY MONITOR SECCHI DISK TRANSPARANCY DATA
YEARLY COMPARISONS (1984-1997)
MINIMUM
AVERAGE
MAXIMUM
YEAR
1984
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
LOW
MODERATE
HIGH
0
2
4
6
8
SECCHI DISK TRANSPARENCY (meters)



CRESCENT LAKE - SITE 6 CENTER
LAY MONITOR CHLOROPHYHLL a DATA
YEARLY COMPARISONS (1984-1997)
MINIMUM
AVERAGE
MAXIMUM
YEAR
1984
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
LOW
MODERATE
HIGH
0
1
2
3
4
5
6
7
8
9
10
CHLOROPHYLL a CONCENTRATION (ppb)

Figure 19. Comparison of the 1997 Lake Wentworth, Site 1 Fullers, lay monitor Secchi Disk transparency data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1984-1996). The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk transparency the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 20. Comparison of the 1997 Lake Wentworth, Site 1 Fullers, lay monitor chlorophyll *a* data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1984-1996). The shaded regions on the graph denote the ranges characteristic of low and moderate chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).


LAKE WENTWORTH - SITE 1 FULLERS
LAY MONITOR SECCHI DISK TRANSPARANCY DATA
YEARLY COMPARISONS (1984-1997)
MINIMUM
AVERAGE
MAXIMUM
YEAR
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
LOW
MODERATE
HIGH
0
2
4
6
8
10
SECCHI DISK TRANSPARENCY (meters)

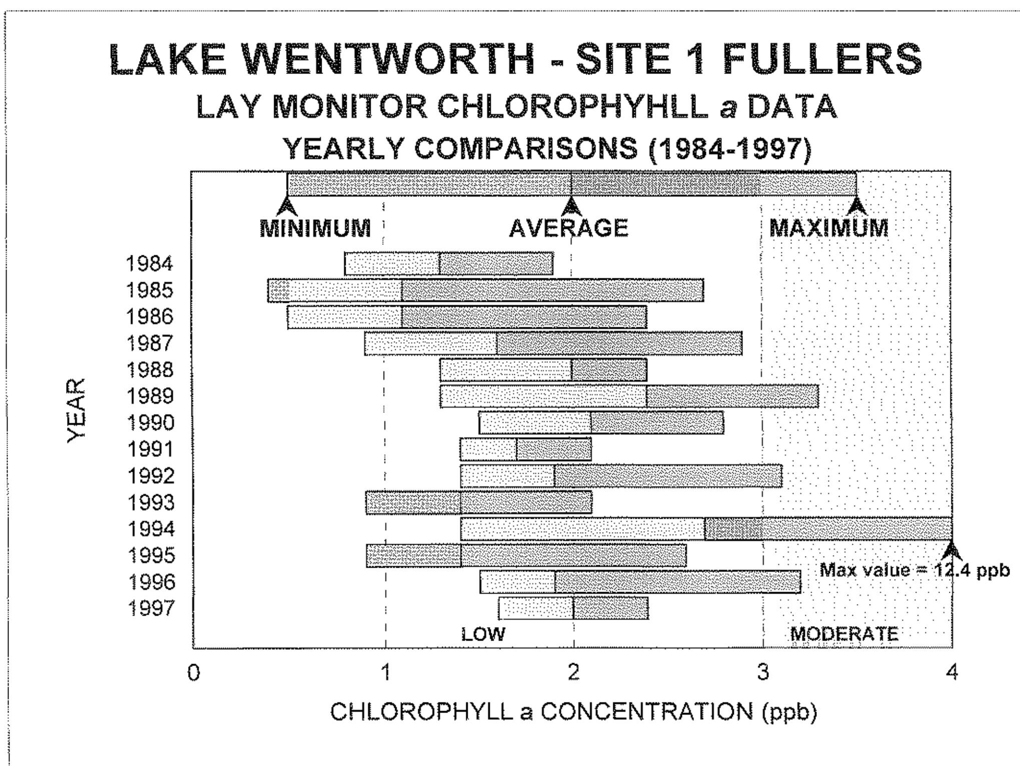
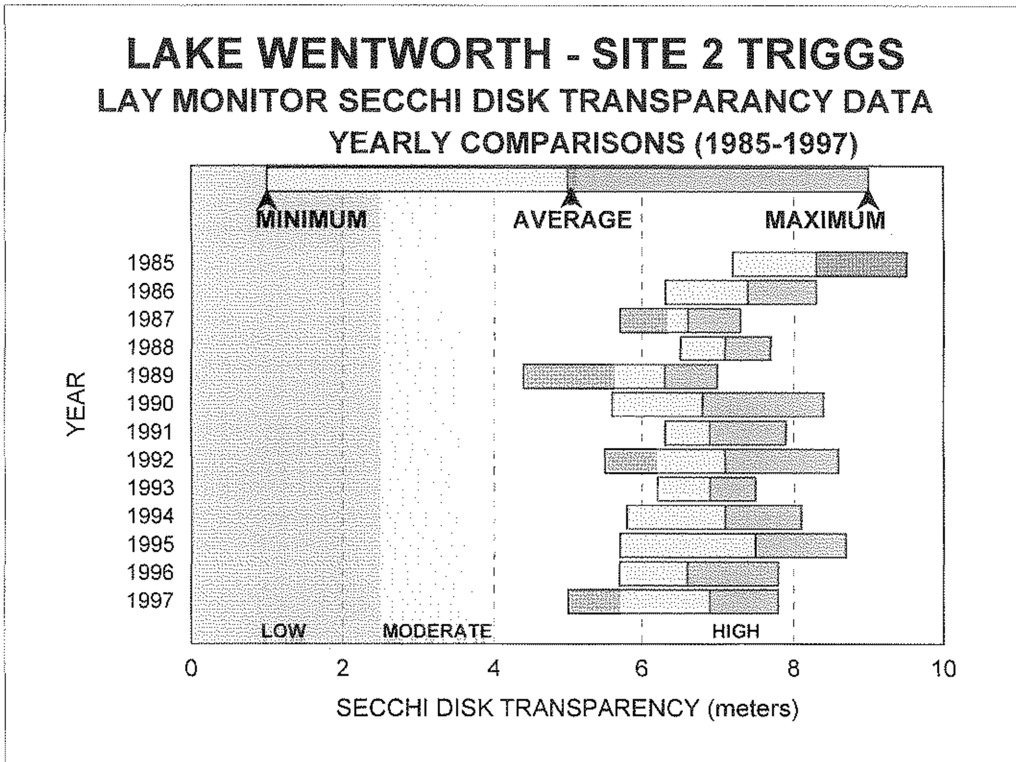
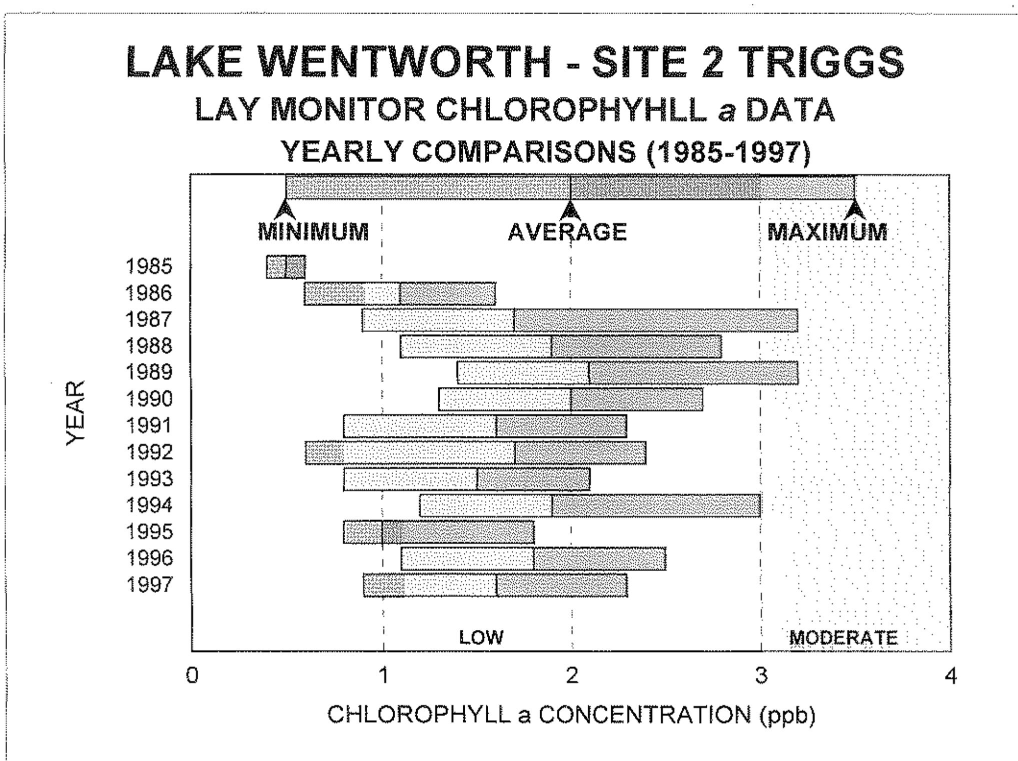

LAKE WENTWORTH - SITE 1 FULLERS
LAY MONITOR CHLOROPHYHLL a DATA
YEARLY COMPARISONS (1984-1997)
MINIMUM
AVERAGE
MAXIMUM
YEAR
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Max value = 12.4 ppb
LOW
MODERATE
0
1
2
3
4
CHLOROPHYLL a CONCENTRATION (ppb)

Figure 21. Comparison of the 1997 Lake Wentworth, Site 2 Triggs, lay monitor Secchi Disk transparency data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1985-1996). The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk transparency the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 22. Comparison of the 1997 Lake Wentworth, Site 2 Triggs, lay monitor chlorophyll *a* data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1985-1996). The shaded regions on the graph denote the ranges characteristic of low and moderate chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).



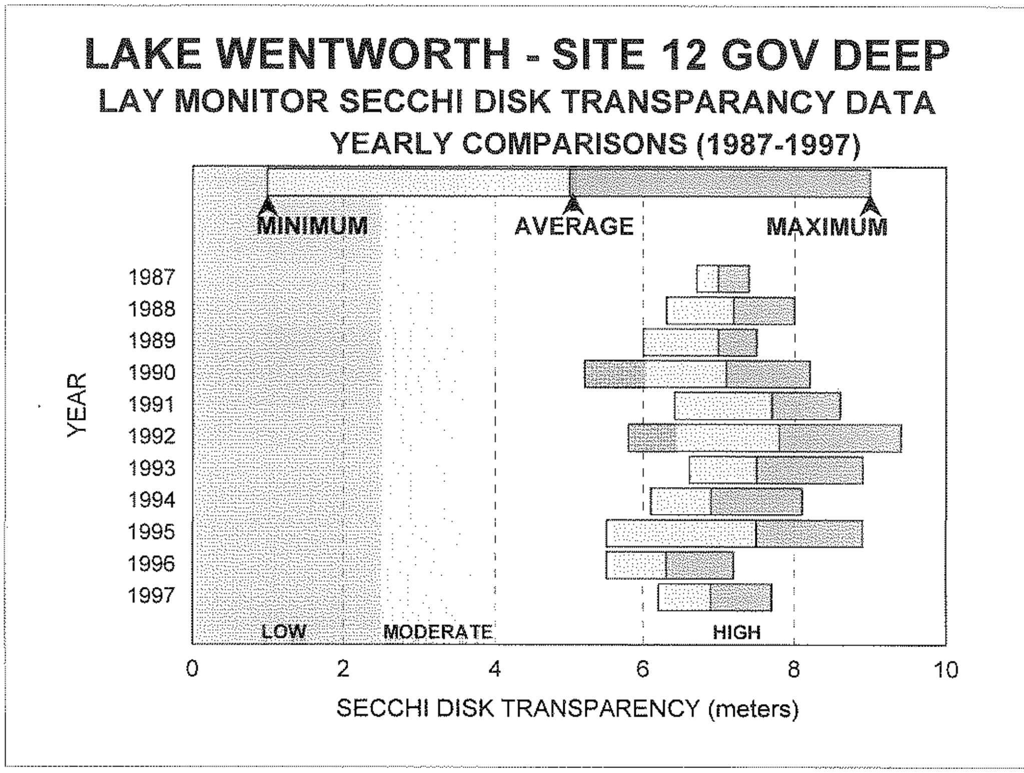
LAKE WENTWORTH - SITE 2 TRIGGS
LAY MONITOR SECCHI DISK TRANSPARANCY DATA
YEARLY COMPARISONS (1985-1997)
MINIMUM
AVERAGE
MAXIMUM
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
YEAR
LOW
MODERATE
HIGH
0
2
4
6
8
10
SECCHI DISK TRANSPARENCY (meters)



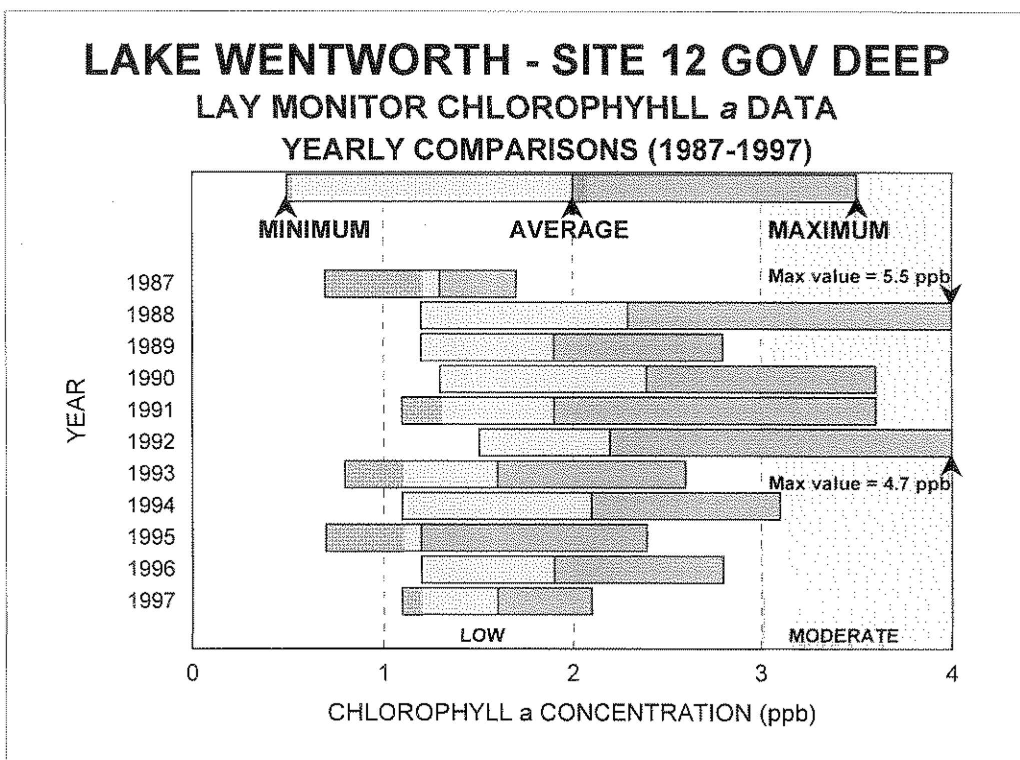
LAKE WENTWORTH - SITE 2 TRIGGS
LAY MONITOR CHLOROPHYHLL a DATA
YEARLY COMPARISONS (1985-1997)
MINIMUM
AVERAGE
MAXIMUM
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
YEAR
LOW
MODERATE
0
1
2
3
4
CHLOROPHYLL a CONCENTRATION (ppb)

Figure 23. Comparison of the 1997 Lake Wentworth, Site 12 Governors Deep, lay monitor Secchi Disk transparency data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1987-1996). The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk transparency the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

Figure 24. Comparison of the 1997 Lake Wentworth, Site 12 Governors Deep, lay monitor chlorophyll *a* data with historical water quality data collected in conjunction with the New Hampshire Lakes Lay Monitoring Program (1987-1996). The shaded regions on the graph denote the ranges characteristic of low and moderate chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).

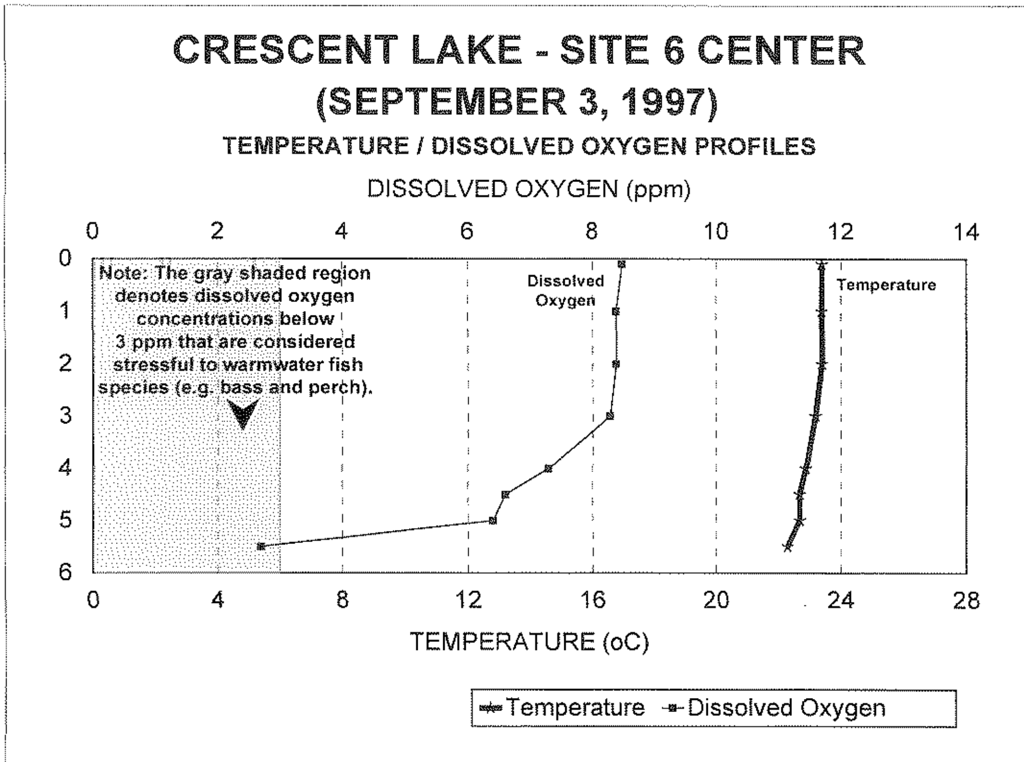


LAKE WENTWORTH - SITE 12 GOV DEEP
LAY MONITOR SECCHI DISK TRANSPARANCY DATA
YEARLY COMPARISONS (1987-1997)
MINIMUM
AVERAGE
MAXIMUM
YEAR
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
LOW
MODERATE
HIGH
0
2
4
6
8
10
SECCHI DISK TRANSPARENCY (meters)

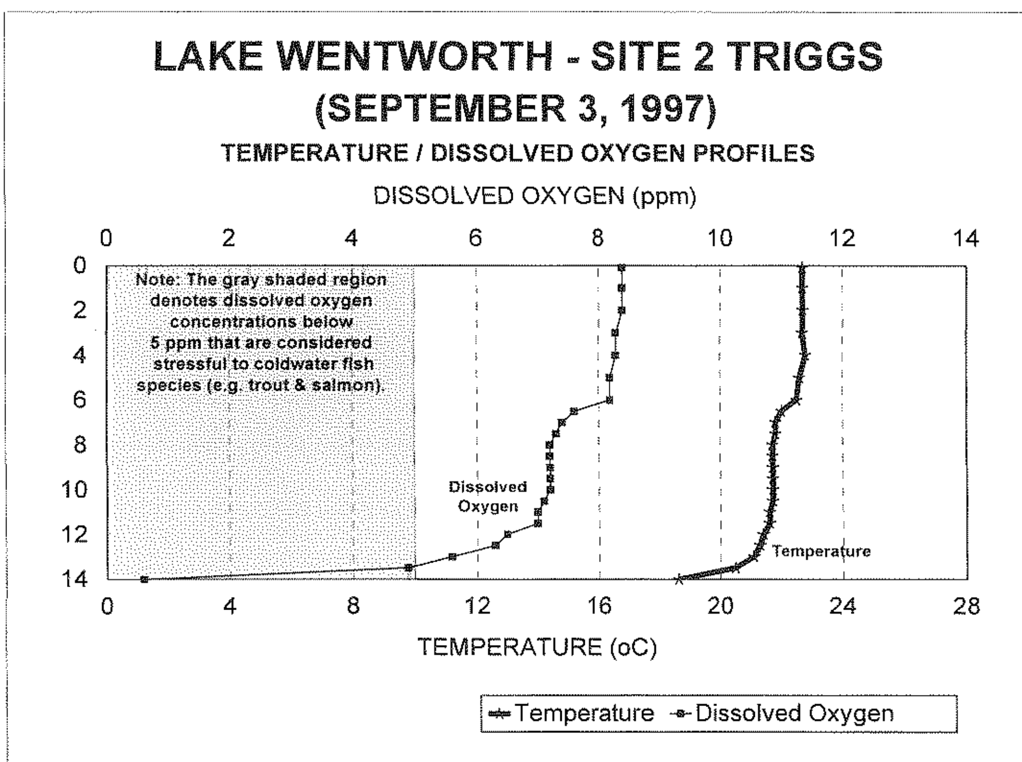


LAKE WENTWORTH - SITE 12 GOV DEEP
LAY MONITOR CHLOROPHYHLL a DATA
YEARLY COMPARISONS (1987-1997)
MINIMUM
AVERAGE
MAXIMUM
Max value = 5.5 ppb
Max value = 4.7 ppb
YEAR
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
LOW
MODERATE
0
1
2
3
4
CHLOROPHYLL a CONCENTRATION (ppb)

Figure 25. Temperature and dissolved profiles collected in (A) Crescent Lake, Site 6 Center, and (B) Lake Winnipesaukee, Site 2 Triggs, on September 3, 1997. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to warmwater (Crescent Lake) and coldwater (Lake Wentworth Lake) fish. The temperature and dissolved oxygen data were collected at one-half meter increments and are reported as degrees Centigrade (°C) and parts per million (ppm), respectively.

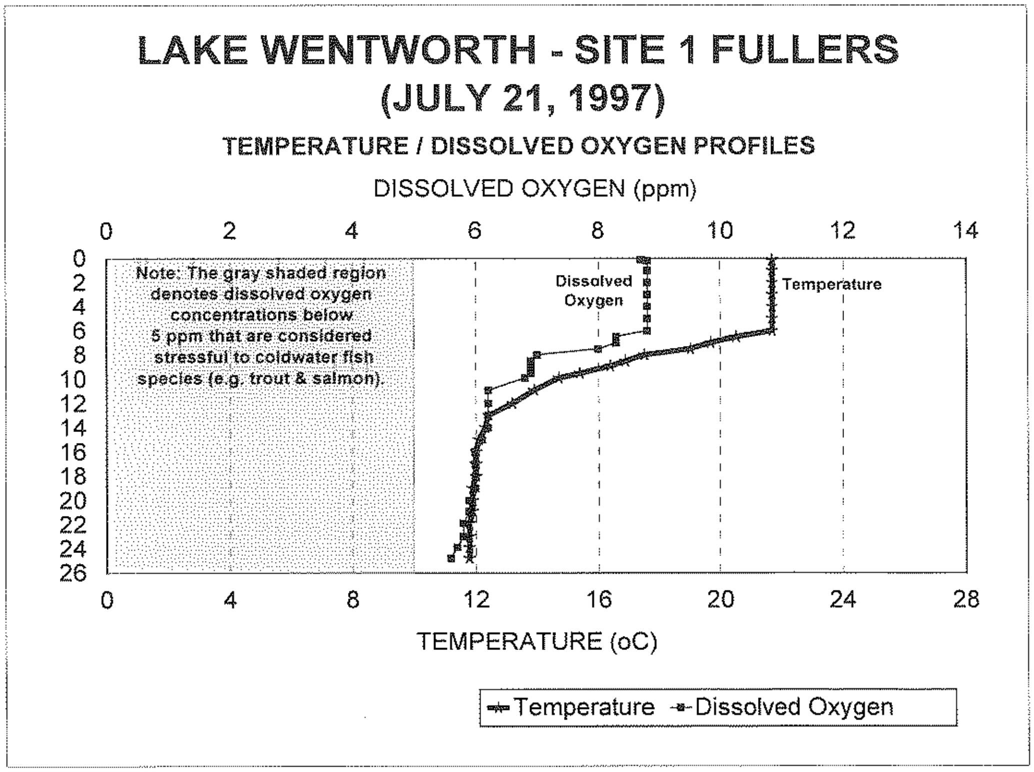


CRESCENT LAKE - SITE 6 CENTER
(SEPTEMBER 3, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 ppm that are considered stressful to warmwater fish species (e.g. bass and perch).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen



LAKE WENTWORTH - SITE 2 TRIGGS
(SEPTEMBER 3, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 ppm that are considered stressful to coldwater fish species (e.g. trout & salmon).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen

Figure 26. Temperature and dissolved profiles collected in Lake Wentworth, Site 1 Fullers, on (A) July 21, 1997 and (B) September 3, 1997. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to coldwater fish. The temperature and dissolved oxygen data were collected at one-half meter increments and are reported as degrees Centigrade (°C) and parts per million (ppm), respectively.


LAKE WENTWORTH - SITE 1 FULLERS
(JULY 21, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 ppm that are considered stressful to coldwater fish species (e.g. trout & salmon).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen

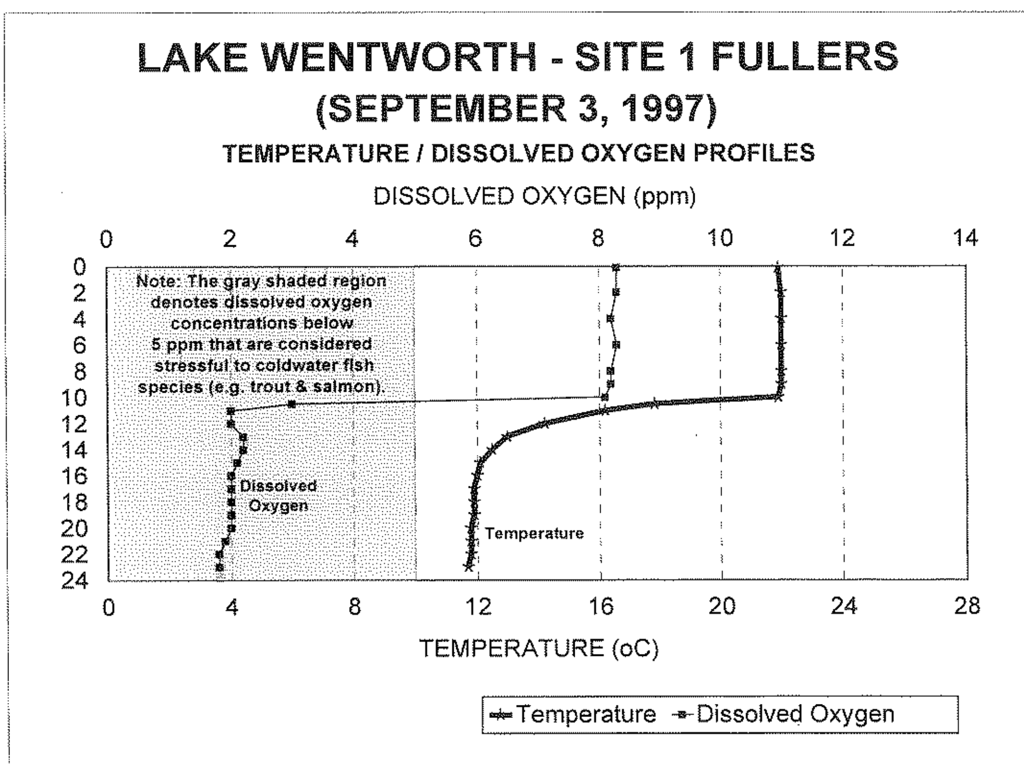
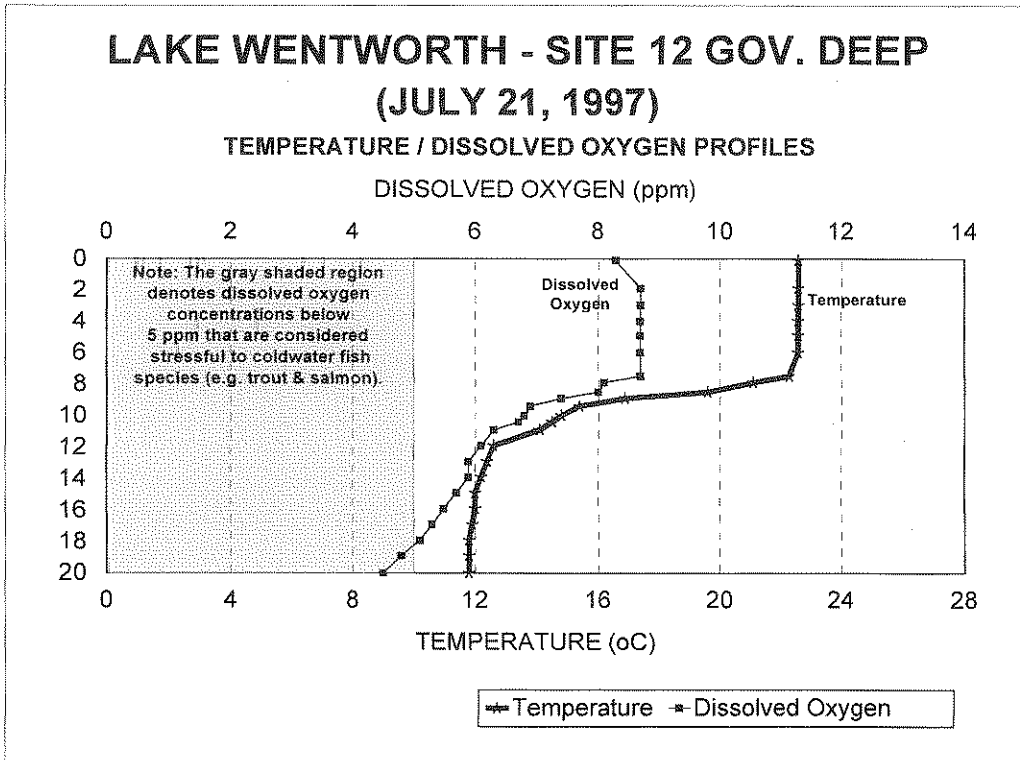
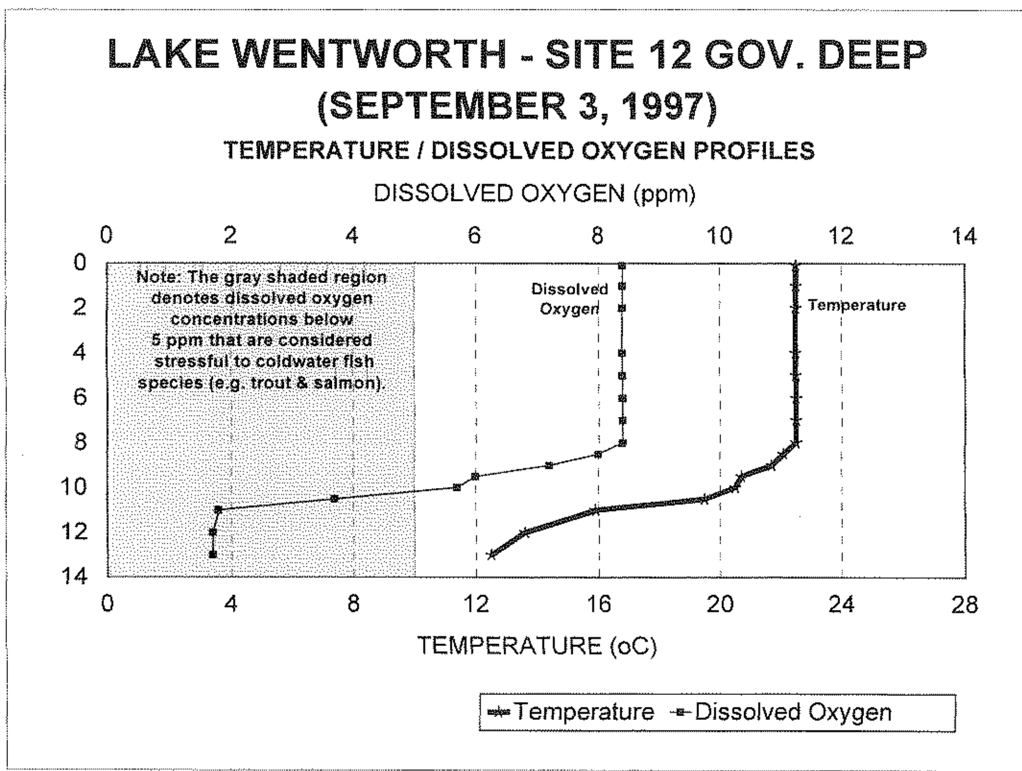

LAKE WENTWORTH - SITE 1 FULLERS
(SEPTEMBER 3, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 ppm that are considered stressful to coldwater fish species (e.g. trout & salmon).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen

Figure 27. Temperature and dissolved profiles collected in Lake Wentworth, Site 12 Governors Deep on (A) July 21, 1997 and (B) September 3, 1997. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to coldwater fish. The temperature and dissolved oxygen data were collected at one-half meter increments and are reported as degrees Centigrade (°C) and parts per million (ppm), respectively.


LAKE WENTWORTH - SITE 12 GOV. DEEP
(JULY 21, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 ppm that are considered stressful to coldwater fish species (e.g. trout & salmon).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen


LAKE WENTWORTH - SITE 12 GOV. DEEP
(SEPTEMBER 3, 1997)
TEMPERATURE / DISSOLVED OXYGEN PROFILES
DISSOLVED OXYGEN (ppm)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 ppm that are considered stressful to coldwater fish species (e.g. trout & salmon).
Dissolved Oxygen
Temperature
TEMPERATURE (oC)
Temperature
Dissolved Oxygen

APPENDIX A

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Crescent Lake, Wolfeboro NH
-- subset of trophic indicators, all sites, 1997

1997 SUMMARY

Average transparency:	5.3	(1997:	11	values;	4.6 -	5.7	range)
Average chlorophyll:	1.7	(1997:	11	values;	1.0 -	2.8	range)
Average color:	15.1	(1997:	11	values;	12.0 -	18.9	range)
Average alk (gray):	5.3	(1997:	11	values;	5.0 -	5.7	range)
Average alk (pink):	6.0	(1997:	11	values;	5.5 -	6.5	range)

Site	Date	Trans-Parency (m)	Chl *a* (ppb)	Color (Pt-Co) units	Alkg (gray) pH 5.1	Alkp (pink) pH 4.6	Total Phos. (ppb)
6 Center	6/13/97	5.2	1.1	18.9	5.4	6.2	-----
6 Center	6/20/97	4.6	2.1	18.0	5.5	6.5	-----
6 Center	6/27/97	-----	1.4	14.6	5.6	6.3	-----
6 Center	7/5/97	5.2	1.0	12.9	5.7	6.3	-----
6 Center	7/11/97	5.7	1.2	12.0	5.6	6.2	-----
6 Center	7/18/97	5.0	1.5	16.3	5.5	6.2	-----
6 Center	7/26/97	5.1	1.9	14.6	5.1	5.5	-----
6 Center	8/2/97	5.5	2.1	13.7	5.0	5.5	-----
6 Center	8/9/97	5.4	1.3	16.3	5.0	5.6	-----
6 Center	8/16/97	5.7	2.1	13.7	5.2	5.8	-----
6 Center	8/30/97	5.3	2.8	15.5	5.2	5.8	-----

<< end of 1997 listing, 11 records >>

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Lake Wentworth, Wolfeboro NH
-- subset of trophic indicators, all sites, 1997

1997 SUMMARY

Average transparency:	7.0	(1997:	24	values;	5.0	-	7.8	range)
Average chlorophyll:	1.8	(1997:	23	values;	0.9	-	2.4	range)
Average color:	15.4	(1997:	22	values;	12.0	-	21.5	range)
Average alk (gray):	4.9	(1997:	23	values;	3.9	-	5.7	range)
Average alk (pink):	5.9	(1997:	23	values;	4.4	-	7.0	range)

Site	Date	Trans-parency (m)	Chl *a* (ppb)	Color (Pt-Co) units	Alkg (gray) pH 5.1	Alkp (pink) pH 4.6	Total Phos. (ppb)
1 Fullers	6/23/97	6.5	2.3	16.3	5.4	6.4	-----
1 Fullers	6/29/97	7.5	1.7	15.5	5.7	6.2	-----
1 Fullers	7/13/97	7.4	1.6	15.5	4.9	6.0	-----
1 Fullers	7/20/97	6.5	2.1	16.3	5.4	6.4	-----
1 Fullers	7/26/97	6.3	1.8	14.6	5.4	6.2	-----
1 Fullers	8/10/97	7.8	2.1	12.0	5.3	6.2	-----
1 Fullers	8/15/97	7.7	2.4	12.0	-----	-----	-----
1 Fullers	8/22/97	6.9	2.0	13.7	5.4	6.6	-----
1 Fullers	9/12/97	7.0	2.1	12.9	5.3	6.4	-----
1 Fullers	9/19/97	6.9	2.1	-----	5.5	6.6	-----
2 Triggs	6/28/97	5.0	0.9	-----	5.4	7.0	-----
2 Triggs	7/6/97	7.8	1.6	21.5	5.2	6.2	-----
2 Triggs	7/12/97	7.3	1.9	18.0	5.0	6.1	-----
2 Triggs	7/27/97	6.7	2.3	16.3	3.9	5.2	-----
2 Triggs	8/3/97	7.6	1.9	16.3	4.6	6.5	-----
2 Triggs	8/10/97	7.6	1.1	16.3	4.5	6.2	-----
2 Triggs	8/16/97	6.5	1.5	18.0	4.6	6.0	-----
12 GovDeep	6/26/97	6.8	1.5	16.3	4.1	4.4	-----
12 GovDeep	7/2/97	6.4	1.1	17.2	4.6	5.0	-----
12 GovDeep	7/14/97	6.3	1.6	15.5	4.2	4.5	-----
12 GovDeep	7/28/97	6.2	1.3	14.6	4.4	4.8	-----
12 GovDeep	8/11/97	7.7	2.0	12.9	4.6	5.2	-----
12 GovDeep	8/24/97	7.7	-----	13.7	4.5	5.0	-----
12 GovDeep	9/13/97	7.1	2.1	13.7	5.2	5.6	-----

<< end of 1997 listing, 24 records >>

Lakes Lay Monitoring Program, U.N.H.
[Lake Wentworth and Crescent Lake FBG Data – 1997]

Site	Date	Depth (meters)	chl *a* (ug/l)	Color (CPU)	CO_2 (mg/l)	Alkalinity gray end point (mg/l)	Alkalinity pink end point (mg/l)	Total Phos. (mg/m^3)
1 Fullers	7/21/97	0-6.0	3.0	13.7	-----	5.4	5.9	6.1
1 Fullers	7/21/97	0.5	3.3	15.5	1.2	5.3	5.8	-----
1 Fullers	7/21/97	3.0	-----	-----	1.1	5.3	5.8	-----
1 Fullers	7/21/97	7.0	13.1	18.0	1.6	5.3	5.8	8.6
1 Fullers	7/21/97	24.0	-----	-----	5.6	5.1	5.4	7.4
1 Fullers	9/3/97	0-8.0	2.4	12.0	-----	-----	-----	7.0
1 Fullers	9/3/97	12.0	1.3	17.2	23.8	-----	-----	9.6
1 Fullers	9/3/97	22.0	-----	-----	23.6	5.3	5.9	11.7
2 Triggs	9/3/97	0-8.0	2.0	11.2	-----	-----	-----	6.7
2 Triggs	9/3/97	0.5	-----	-----	-----	5.0	5.5	-----
2 Triggs	9/3/97	13.5	-----	-----	8.0	5.3	5.8	6.7
12 Gov Deep	7/21/97	0-7.5	2.1	12.9	-----	5.4	5.8	6.8
12 Gov Deep	7/21/97	0.5	2.4	13.7	1.1	5.2	5.7	-----
12 Gov Deep	7/21/97	3.0	-----	-----	1.1	5.2	5.6	-----
12 Gov Deep	7/21/97	10.0	2.5	40.4	4.3	5.4	5.9	-----
12 Gov Deep	7/21/97	19.5	-----	-----	6.3	5.1	5.5	7.4
12 Gov Deep	9/3/97	0-8.0	2.0	11.2	-----	-----	-----	8.8
12 Gov Deep	9/3/97	0.5	-----	-----	1.8	-----	-----	-----
12 Gov Deep	9/3/97	9.5	1.8	12.0	5.6	-----	-----	-----
12 Gov Deep	9/3/97	12.5	-----	-----	22.2	5.5	5.9	9.6
6 Center	9/3/97	0-5.0	2.8	12.0	-----	-----	-----	8.8
6 Center	9/3/97	0.5	-----	-----	-----	5.6	6.0	-----
6 Center	9/3/97	3.5	4.6	15.5	-----	-----	-----	12.7

Site	Date	Secchi Disk Transparency (meters)
1 Fullers	07/21/97	5.5 meters
1 Fullers	09/03/97	8.2 meters
2 Triggs	09/03/97	7.5 meters
12 Gov Deep	07/21/97	6.1 meters
12 Gov Deep	09/03/97	7.6 meters
6 Center	09/03/97	5.5 meters (Secchi Disk was on the lakebottom)

Lake Wentworth and Crescent Lake Temperature and Dissolved Oxygen Data
(FBG Data – 1997)

Lake	Site	Date	Depth (meters)	Temperature (^{o}C)	Dissolved Oxygen (mg/l)
Crescent	6 Center	09/03/97	0.1	23.4	8.5
Crescent	6 Center	09/03/97	1.0	23.4	8.4
Crescent	6 Center	09/03/97	2.0	23.4	8.4
Crescent	6 Center	09/03/97	3.0	23.2	8.3
Crescent	6 Center	09/03/97	4.0	22.9	7.3
Crescent	6 Center	09/03/97	4.5	22.7	6.6
Crescent	6 Center	09/03/97	5.0	22.7	6.4
Crescent	6 Center	09/03/97	5.5	22.3	2.7
Wentworth	1 Fullers	09/03/97	0.1	21.9	8.3
Wentworth	1 Fullers	09/03/97	2.0	22.0	8.3
Wentworth	1 Fullers	09/03/97	4.0	22.0	8.2
Wentworth	1 Fullers	09/03/97	6.0	22.0	8.3
Wentworth	1 Fullers	09/03/97	8.0	22.0	8.2
Wentworth	1 Fullers	09/03/97	9.0	22.0	8.2
Wentworth	1 Fullers	09/03/97	10.0	21.9	8.1
Wentworth	1 Fullers	09/03/97	10.5	17.8	3.0
Wentworth	1 Fullers	09/03/97	11.0	16.2	2.0
Wentworth	1 Fullers	09/03/97	12.0	14.2	2.0
Wentworth	1 Fullers	09/03/97	13.0	13.0	2.2
Wentworth	1 Fullers	09/03/97	14.0	12.5	2.2
Wentworth	1 Fullers	09/03/97	15.0	12.1	2.1
Wentworth	1 Fullers	09/03/97	16.0	12.0	2.0
Wentworth	1 Fullers	09/03/97	17.0	11.9	2.0
Wentworth	1 Fullers	09/03/97	18.0	11.9	2.0
Wentworth	1 Fullers	09/03/97	19.0	11.9	2.0
Wentworth	1 Fullers	09/03/97	20.0	11.8	2.0
Wentworth	1 Fullers	09/03/97	21.0	11.8	1.9
Wentworth	1 Fullers	09/03/97	22.0	11.8	1.8
Wentworth	1 Fullers	09/03/97	23.0	11.7	1.8
Wentworth	2 Triggs	09/03/97	0.1	22.7	8.4
Wentworth	2 Triggs	09/03/97	1.0	22.7	8.4
Wentworth	2 Triggs	09/03/97	2.0	22.7	8.4
Wentworth	2 Triggs	09/03/97	3.0	22.7	8.3
Wentworth	2 Triggs	09/03/97	4.0	22.8	8.3
Wentworth	2 Triggs	09/03/97	5.0	22.6	8.2
Wentworth	2 Triggs	09/03/97	6.0	22.5	8.2
Wentworth	2 Triggs	09/03/97	6.5	22.0	7.6
Wentworth	2 Triggs	09/03/97	7.0	21.8	7.4
Wentworth	2 Triggs	09/03/97	7.5	21.8	7.3
Wentworth	2 Triggs	09/03/97	8.0	21.7	7.2
Wentworth	2 Triggs	09/03/97	8.5	21.7	7.2
Wentworth	2 Triggs	09/03/97	9.0	21.7	7.2

Lake Wentworth and Crescent Lake Temperature and Dissolved Oxygen Data (FBG Data – 1997)

Lake	Site	Date	Depth (meters)	Temperature (^{0}C)	Dissolved Oxygen (mg/l)
Wentworth	2 Triggs	09/03/97	9.5	21.7	7.2
Wentworth	2 Triggs	09/03/97	10.0	21.7	7.2
Wentworth	2 Triggs	09/03/97	10.5	21.7	7.1
Wentworth	2 Triggs	09/03/97	11.0	21.6	7.0
Wentworth	2 Triggs	09/03/97	11.5	21.6	7.0
Wentworth	2 Triggs	09/03/97	12.0	21.4	6.5
Wentworth	2 Triggs	09/03/97	12.5	21.3	6.3
Wentworth	2 Triggs	09/03/97	13.0	21.1	5.6
Wentworth	2 Triggs	09/03/97	13.5	20.5	4.9
Wentworth	2 Triggs	09/03/97	14.0	18.6	0.6
Wentworth	12 Gov. Deep	09/03/97	0.1	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	1.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	2.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	4.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	5.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	6.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	7.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	8.0	22.5	8.4
Wentworth	12 Gov. Deep	09/03/97	8.5	22.1	8.0
Wentworth	12 Gov. Deep	09/03/97	9.0	21.7	7.2
Wentworth	12 Gov. Deep	09/03/97	9.5	20.7	6.0
Wentworth	12 Gov. Deep	09/03/97	10.0	20.5	5.7
Wentworth	12 Gov. Deep	09/03/97	10.5	19.5	3.7
Wentworth	12 Gov. Deep	09/03/97	11.0	15.9	1.8
Wentworth	12 Gov. Deep	09/03/97	12.0	13.6	1.7
Wentworth	12 Gov. Deep	09/03/97	13.0	12.5	1.7

Lake Wentworth FBG Data (Site 1 Fullers 7/21/97)

Date	Depth (meters)	Temp (^oC)	Sp Cond (uS/cm)	Diss. O_2 (mg/L)	pH	ORP (mV)	Turbidity (NTU)
7/21/97	0.1	21.7	37.0	8.7	7.1	168.0	0.4
7/21/97	0.2	21.7	40.0	8.8	7.0	171.0	0.5
7/21/97	1.0	21.7	40.0	8.8	7.0	174.0	0.6
7/21/97	2.0	21.7	42.0	8.8	7.0	175.0	0.4
7/21/97	3.0	21.7	40.0	8.8	7.0	177.0	0.5
7/21/97	4.0	21.7	40.0	8.8	7.0	180.0	0.2
7/21/97	5.0	21.7	40.0	8.8	7.0	181.0	0.6
7/21/97	6.0	21.7	39.0	8.8	6.9	184.0	1.0
7/21/97	6.5	20.5	40.0	8.3	6.7	184.0	1.0
7/21/97	7.0	19.7	40.0	8.3	6.6	188.0	0.7
7/21/97	7.5	19.0	39.0	8.0	6.5	192.0	0.9
7/21/97	8.0	17.5	40.0	7.0	6.3	195.0	1.1
7/21/97	8.5	16.9	41.0	6.9	6.3	198.0	0.2
7/21/97	8.9	16.4	40.0	6.9	6.3	200.0	0.2
7/21/97	9.5	15.4	40.0	6.9	6.2	201.0	0.2
7/21/97	9.9	14.7	39.0	6.8	6.2	203.0	0.3
7/21/97	10.9	13.9	40.0	6.2	6.2	204.0	0.1
7/21/97	12.0	13.2	39.0	6.2	6.2	205.0	0.1
7/21/97	13.0	12.4	40.0	6.2	6.2	205.0	0.1
7/21/97	14.0	12.3	39.0	6.2	6.2	206.0	0.1
7/21/97	15.0	12.1	39.0	6.1	6.2	207.0	0.1
7/21/97	16.0	12.0	39.0	6.0	6.2	208.0	0.0
7/21/97	17.0	12.0	39.0	6.0	6.2	208.0	0.1
7/21/97	18.0	12.0	39.0	6.0	6.2	208.0	0.2
7/21/97	19.0	11.9	40.0	6.0	6.2	209.0	0.1
7/21/97	20.0	11.9	40.0	5.9	6.2	209.0	0.0
7/21/97	20.9	11.9	40.0	5.9	6.2	210.0	0.1
7/21/97	21.9	11.8	40.0	5.8	6.2	210.0	0.1
7/21/97	23.0	11.8	40.0	5.8	6.2	211.0	0.2
7/21/97	23.9	11.8	40.0	5.7	6.2	211.0	0.1
7/21/97	24.8	11.8	40.0	5.6	6.1	212.0	0.2

Lake Wentworth FBG Data (Site 12 Governors Deep 7/21/97)

Date	Depth (meters)	Temp (^oC)	Sp Cond (uS/cm)	Diss. O_2 (mg/L)	pH	ORP (mV)	Turbidity (NTU)
7/21/97	0.1	22.6	39.0	8.3	7.1	175.0	0.5
7/21/97	1.9	22.6	42.0	8.7	7.2	172.0	0.3
7/21/97	3.0	22.6	40.0	8.7	7.1	174.0	0.4
7/21/97	4.0	22.6	40.0	8.7	7.1	175.0	0.3
7/21/97	4.9	22.6	39.0	8.7	7.1	176.0	0.3
7/21/97	6.0	22.6	39.0	8.7	7.1	178.0	0.3
7/21/97	7.5	22.3	40.0	8.7	7.0	182.0	0.4
7/21/97	7.9	21.1	41.0	8.1	6.7	186.0	0.2
7/21/97	8.5	19.6	40.0	8.0	6.5	190.0	0.8
7/21/97	8.9	16.9	40.0	7.4	6.3	197.0	0.2
7/21/97	9.4	15.4	40.0	6.9	6.2	200.0	0.2
7/21/97	10.0	14.8	43.0	6.8	6.2	199.0	0.2
7/21/97	10.4	14.5	40.0	6.7	6.2	200.0	0.1
7/21/97	10.9	14.1	41.0	6.3	6.2	201.0	0.4
7/21/97	11.9	12.6	40.0	6.1	6.2	203.0	0.1
7/21/97	12.9	12.4	40.0	5.9	6.2	204.0	0.1
7/21/97	13.9	12.2	41.0	5.9	6.2	204.0	0.0
7/21/97	14.9	12.0	39.0	5.7	6.2	205.0	0.2
7/21/97	15.9	12.0	41.0	5.5	6.1	206.0	0.1
7/21/97	16.9	11.9	40.0	5.3	6.1	206.0	0.1
7/21/97	16.9	11.9	40.0	5.3	6.1	207.0	0.1
7/21/97	17.9	11.8	40.0	5.1	6.1	207.0	0.0
7/21/97	18.9	11.8	40.0	4.8	6.1	208.0	0.1
7/21/97	20.0	11.8	40.0	4.5	6.1	208.0	0.1

APPENDIX B

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia, Cyclops, Bosmina*, and *Kellicottia.*